UNITED STATES DEPARTMENT OF AGRICULTURE

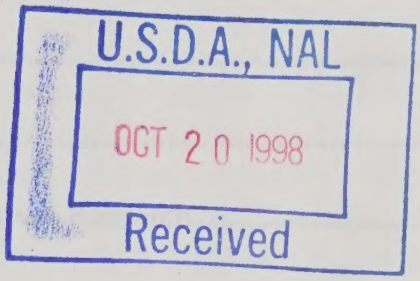
AGRICULTURAL RESEARCH SERVICE

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened By Implementation of FQPA

Selected Examples of ARS Program Activities

Potential At-Risk Pesticide Alternatives

ARS Inventory and Status



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Beltsville, Maryland
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Table of Contents

Table of Contents

Introduction

The provisions of FQPA passed in 1996 require EPA to reassess all pesticide tolerances within ten years of passage of the Act, and to change its standard for evaluating pesticides from an acceptable risk/benefit profile to a reasonable expectation of no harm. EPA is to evaluate the riskiest one-third of currently used pesticides within the next couple of years. In the first phase of tolerance reassessment, EPA plans on reviewing the tolerances of 39 organophosphates, 21 carbamates and 35 B-1/B2 potential carcinogen pesticides; compounds within these groups are used as insecticides, nematicides, fungicides, herbicides, and antimicrobial agents.

Alternative pest management approaches must be developed to replace pesticides removed from the marketplace as a result of regulatory action, and a determination must be made as to what alternative tactics are in the development pipeline or in the registration process, and what is required to bring them into full utilization. Several potentially impacted grower organizations have approached ARS and requested that the Agency take a lead in responding to the pending crisis as the compounds are lost for pest control use by the agricultural industry within the next two years. This document includes the results of an initial survey and inventory of ARS research activities that have, or have the potential of generating substitutes and alternatives to at-risk pesticides. This will be a continuing process and periodic updates of the document will be made. Technologies that have been out on the market and being use are not included to any extent in this initial inventory.

ARS considers research on safe alternatives to at-risk pesticides as one of its highest priorities. The agency has recently implemented a number of activities in response to this pending crisis, including undertaking this initial inventory and status assessment of ARS research relevant to at-risk organophosphate and carbamate pesticides; scheduling meetings and workshops between scientists, commodity groups and others to better define specific critical research and action needed beyond current programs; and scheduling periodic informational exchange and coordination meetings involving the USDA Office of Pest Management Policy, other Federal and State agencies, the USDA IPM Subcommittee, ARS Management, and the ARS National Program Teams.

ARS over the years has been actively conducting extensive component and IPM research on alternative methods of pest control to reduce the reliance on at-risk and other broad spectrum chemical pesticides. This research includes projects to develop environmentally-friendly pest controls, including the use of natural enemies, microbial agents, host-resistance and cultural practices, behavioral disruptors and other biorational products, and improved pesticide application technologies. Target pests include insects, mites, ticks, plant pathogens and nematodes, and weeds. Additionally, ARS has implemented five areawide IPM pest management projects in partnership with other Federal and State institutions and the private sector to help farmers adopt, implement, and use appropriately new technologies as replacements for at-risk pesticides; these projects include mating disruption for codling moth on tree fruits in the Pacific Northwest, which has resulted in an 80-100% reduction in Guthion use; the use of attract and kill technology in the Midwest for corn rootworm that is expected to reduce populations by greater than 90 percent with less than 10 percent of the chemicals used in current

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corn rootworm control regimes; a project on insects of stored grain in the Midwest using early aeration to cool grain and reduce insect and mold population growth; a leafy spurge weed project in the Northern Great Plains using a natural predator and other technologies, thus decreasing substantially the use of herbicides; and a project using early-season spraying of an insect virus in the South to suppress populations of the cotton bollworm and tobacco budworm.

Other replacement technologies are in the developmental pipeline, or in the registration process, many of which are included in this document. Examples include the use of a natural product derived from kaolin clay that possesses high repellency properties against arthropod pests and disease-causing microorganisms of plants; the use of photoactive dyes for control of a number of insect pests, including fruit flies, Colorado potato beetle, and corn rootworm and the use of synthetic sugar esters that are effective against soft-bodied insects. Other technologies ARS has developed over the years include sterile insect techniques, natural enemies of pests, microbial biocontrol agents, host resistance, repellents, traps, and other biorational products.

ARS continues to support and facilitate through research the registration of minor-use pesticides, which plays an important role in ensuring that the Agency meets its commitment to provide the necessary data to EPA to more quickly bring these chemicals into use where no or limited alternatives are presently available. ARS also is assisting in the Continuing Survey of Food Intakes by Individuals (CSFII), which will provide EPA with commodity-level food intake data for use in tolerance reassessment. When completed, CSFII and a companion survey, "Supplemental Children's Survey" will provide food intake data for approximately 5,700 children, 18 months old and less, and 5000 children 9 years old and less. The data will provide fundamental information for a comprehensive risk assessment of potential effects of pesticide residues on infants and children.

An Office of Pest Management Policy was established on September 8, 1997, to improve USDA's ability to address FQPA by improving integration and coordination of pest management and pesticide data programs, and by strengthening communications with the existing network of grower organizations and crop specialists at land-grant institutions.

Research funded by ARS is expected to develop and/or demonstrate in field IPM approaches, efficacious, cost effective and environmentally sound methods to substitute for at-risk pesticides as a result of FQPA implementation. The research will also help provide minor-use chemicals and biorationals as alternatives for at-risk chemical pesticides. ARS will continue to coordinate and focus its pest management resources to address the concerns and needs of commodity groups who will be impacted by FQPA, and to strengthen its national program on at-risk pesticide substitutes and alternatives.

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PRIORITY LIST OF PESTICIDES

[Pesticides that will be first to undergo review of tolerances by EPA, as required by the Food Quality Protection Act of 1996]

ORGANOPHOSPHATES

Acephate—I
Azinphos-methyl—I
Bensulide—H
Chlorethoxyfos—I
Chlorpyrifos—I
Chlorpyrifos methyl—I
Coumaphos—I
DEF—Defoliant
Diazinon—I
Dichlorvos—I
Dicrotophos—I
Dimethoate—I
Disulfoton—I
Ethion—I
Ethoprop—I, N
Ethyl parathion—I
Fenamiphos—I, N
Fenitrothion—I
Fenthion—I
Fonofos—I
Isofenphos—I
Malathion—I
Methamidophos—I
Methidathion—I
Methyl parathion—I
Naled—I
Oxydemeton methyl—I
Phorate—I
Phosmet—I
Phostebupirim—I
Pirimiphos methyl—I
Profenofos—I
Propetamphos—I
Sulfotepp—I
Sulprofos—I
Temephos—I
Terbufos—I
Tetrachlorvinphos—I
Trichlorfon—I

CARBAMATES

2EEEBC—F
Aldicarb—I, N
Asulam—H
Bendiocarb—I
Benomyl—F
Carbaryl—I
Carbendazim—F
Carbofuran—I, N
Chlorpropham—H
Desmidipham—H
Fenoxycarb—I
Formetanate HC—I
Methiocarb—I
Methomyl—I
Oxamyl—I, N
Phenmedipham—H
Propamocarb hydrochloride—F
Propoxur—I
Thiodicarb—I
Thiophanate methyl—F
Troysan KK—AM, F

PRIORITY LIST OF PESTICIDES—Continued

[Pesticides that will be first to undergo review of tolerances by EPA, as required by the Food Quality Protection Act of 1996]

POTENTIAL CARCINOGENS (B1's AND B2's)

Acetochlor—H
Aciflourfen sodium—H
Alachlor—H
Amitrol—H
Cacodylic acid—H
Captan—F
Chlorothalonil—F
Creosote—wood preservative
Cyproconazole—F
Daminozide (Alar)—growth retardant
ETO—fumigant, sterilant
Fenoxycarb—IGR
Folpet—F
Formaldehyde—fumigant, germicide
Heptachlor—I
Iprodione—F
Lactofen—H
Lindane—I
Mancozeb—F
Maneb—F
Metam sodium—F, I, H, N, soil fumigant
Metiram—F
MGK repellent—repellent, synergist
Orthophenylphenol—AM, F, virucide
Oxythioquinox—I
Pentachlorophenol—F
Pronamide—H
Propargite—I
Propoxur—I
Propylene oxide—AM, I, F
Telone—N, soil fumigant
Terrazole—F
Thiodicarb—I
TPTH—F
Vinclozolin—F

AAbbreviations: AM = antimicrobial; I = insecticide; F = fungicide; IGR = insect growth regulator; H = herbicide; N = nematicide.

Selected Examples of Potential Alternatives
ARS Program Activities

A. Chemical and Nonchemical Alternatives Research

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Tobacco budworm, beet armyworm, boll weevil; **(b) Commodity:** cotton, vegetables and other field crops; **(c) Specific Endangered Pesticides:** Sulporfus, profenofos, diodicarb, methomil, acephate, chlorpyrifos, thiodicarb, azinphos-methyl, methyl parathion.

- **(a) Key ARS Location(s):** Weslaco, Texas; **(b) Contact:** Gary Elzen; **(c) CRIS Project Number:** 6204-22000-011-00D and 6204-22000-001-00D.

- **(a) Key Alternative Technology:** Alternative chemicals with unique mode of action such as fipronil (phenylpyrosol) and natural product insecticides (spinosad); **(b) Developmental Status:** ARS in cooperation with commercial industry is testing these chemicals for use and comparing them to the organophosphate and carbamates, as well as their effects on beneficial insects; **(c) Estimated Time Frame to End-User:** Spinosad was recently registered by DowElanco, Inc.

- **Constraints to Adoption:** Possible differential in cost and efficiency compared to the organophosphates and carbamates.

- **Positive Attributes of Alternative Technology:** New chemistry and selective mode of action, and potentially less hazardous to beneficial insects such as *Catalaccus grandis* (fipronil); lower toxicity to mammals.

- **CRADA in Place/Name of Company:** Informal cooperation with DowElanco, Inc., and other companies such as Rhone-Ponlenc Ag Co.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Field crop insect pests; **(b) Commodity:** Minor crops, vegetable and other agronomic crops; **(c) Specific Endangered Pesticides:** Methamidophos, acephate, disulfoton, methyl parathion, malathion, methoxychlor, diazinon, dimethoate, and lannate.

- **(a) Key ARS Location(s):** Tifton, Georgia and various other ARS locations; **(b) Contact:** William Johnson; **(c) CRIS Project Number:** 0500-00007-040-00D.

- **(a) Key Alternative Technology:** Substitute pesticides being examined in the IR-4 minor use program, such as imidacloprid; **(b) Developmental Status:** selective testing against pests and the development of data on residues, the effectiveness and crop safety for pest control products important to producers of minor food crops and ornamentals, is a continuing activity; **(c) Estimated Time Frame to End-User:** One to three years.

- **Constraints to Adoption:** EPA registration.

- **Positive Attributes of Alternative Technology:** Safer and more environmentally-friendly that the organophosphates and carbamates.

- **CRADA in Place/Name of Company:** No CRADA in place.

Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Insects, mites, plant pathogens and weeds; **(b) Commodity:** numerous field crops; **(c) Specific Endangered Pesticides:** organophosphates and carbamates in general; decrease amount used through improved aerial application.

- **(a) Key ARS Location(s):** College Station, Texas; **(b) Contact:** Ivan Kirk; **(c) CRIS Project Number:** 6202-22000-012-00D.

- **(a) Key Alternative Technology:** Improved aerial pesticide application technology (electrostatic spray boom and flow-control devices; **(b) Developmental Status:** Research is on-going to reduce the amount of insecticide applied and decrease spray drift; **(c) Estimated Time Frame to End-User:** One to two years to end-user.

- **Constraints to Adoption:** Cost of retrofitting airplanes, but this is a one time expenditure.

- **Positive Attributes of Alternative Technology:** Decrease spray drift of pesticides and reduction of pesticide amounts.

- **CRADA in Place/Name of Company:** Saploc, Inc., and Southwestern Sprayers.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Formosan Subterranean Termite (FST); **(b) Commodity**: home and wooden structures, live trees; **(c) Specific Endangered Pesticides**: chlorpyrifos.

- **(a) Key ARS Location(s)**: New Orleans, Louisiana **(b) Contact**: Alan Lax; **(c) CRIS Project Number**: 6435-32000-001-00D.

- **(a) Key Alternative Technology**: Alternative termiticide barriers include the currently registered pyrethroid termiticides Dragnet FT and Prelude (permethrin), Demon TC and Prevail FT (cypermethrin), Biflex TC (bifenthrin), tribute (fenvalerate) and DeltaGard TC (deltamethrin, registration pending); termiticide area treatments currently consists of the non-repellent Premise 75 (imidacloprid, a chloronicotinyl); fipronil is soon to be registered; baiting systems currently available through the pest control industry include Sentricon (hexaflumuron, a chitin synthesis inhibitor) and Firstline (sulfluramid, a metabolic poison); Terminate (sulfluramid also) is available as an over-the-counter product; dimilin (diflubenzuron, also a chitin inhibitor) and hydramethylnon (a metabolic poison similar to sulfluramid) may also soon become available as termite baits; Other termite control strategies may include the incorporation of structural components into buildings which are made inedible or toxic; disodium octaborate tetrahydrates is the form of borate being used most widely today for termite prevention; biological control could include the use of entomopathogenic nematodes, pathogenic fungi, or other biologically active systems; **(b) Developmental Status:** Biologically-based technologies research has just been initiated; **(c) Estimated Time Frame to End-User:** up to 10 years.

- **Constraints to Adoption**: None except private industry may initially be hesitant to use biological control agents due to labor intensive methods.

- **Positive Attributes of Alternative Technology**: Biological controls are self-sustaining.

- **CRADA in Place/Name of Company:** None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Horn flies, stable flies, and lice; **(b) Commodity**: beef cattle and dairy cattle; **(c) Specific Endangered Pesticides**: coumaphos, diazinon, primophos, methyl, chlorpyrifos, malathion, dichlorvos, dioxathion, and stirofos.

- **(a) Key ARS Location(s)**: Kerrville, Texas; **(b) Contact**: Sidney Kunz; **(c) CRIS Project Number**: 6205-32000-016-00D.

- **(a) Key Alternative Technology**: Pyrethroids, available on the market. (However, serious resistance problems and loss of organophosphates as substitutes with different mode of action presents a problem); Avermectins, such as ivermectin, moxidectin, doramectin, eprinomectin, are available on the market, and diflubenzuron is available on the market; **(b) Developmental Status:** Already on the market, but screening is in progress; **(c) Estimated Time Frame to End-User**: up to 5 years.

- **Constraints to Adoption**: No major constraints; pyrethroids result in rapid development of resistance and avermectins are expensive.

- **Positive Attributes of Alternative Technology**: Safe, low residues, persistent.

- **CRADA in Place/Name of Company:** None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: *Boophilus annulatus*, the cattle tick; *B. microplus*, the southern cattle tick; **(b) Commodity**: cattle, horses, and wildlife; **(c) Specific Endangered Pesticides**: coumaphos.

- **(a) Key ARS Location(s)**: Kerrville, Texas; **(b) Contact**: John George; **(c) CRIS Project Number**: 6205-32000-015-00D.

- **(a) Key Alternative Technology**: Amitraz - This product has been tested in a dipping vat for the control of *B. microplus* on cattle. A 12% AI EC formulation of this acaricide is produced by Hoechst Roussel Vet and is labeled for application as a whole body spray;
  (b) Developmental Status: already available, tests on toxic doses under sporadic tests to detect resistance; **(c) Estimated Time Frame to End-User**: 3-5 years.

- **Constraints to Adoption**: The primary disadvantage of this acaricide is that it cannot be used for treating equids because it causes a fatal impaction of the intestine. Labeling would have to be changed to permit the treatment of cattle in dipping vats charged with the product. It is not economically advantageous for the manufacturer to seek a change in label for a product whose only market would be the Cattle Fever Tick Eradication Program.

- **Positive Attributes of Alternative Technology**: Amitraz has a high degree of efficacy against ticks and is suitable for use in the Cattle Fever Tick Eradication Program for the treatment of tick-infested cattle. Southern cattle ticks that are resistant to organophosphate acaricides are fully susceptible to amitraz.

- **CRADA in Place/Name of Company:** None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Parasitic bee mites; **(b) Commodity**: about 90 cultivated crops and honey; **(c) Specific Endangered Pesticides**: coumaphos - coumaphos is one of the most effective benign organophosphates for bee mite control.

- **(a) Key ARS Location(s)**: Weslaco, Texas; Beltsville, Maryland; and Baton Rouge, Louisiana; **(b) Contact**: B. Wilson (Weslaco); H. Shimanuki (Beltsville); and T. Rinderer (Baton Rouge); **(c) CRIS Project Numbers**: 6204-21000-007-00D; 1275-21000-081-00D; and 6413-21000-007-00D.

- **(a) Key Alternative Technology**: Two alternative acaricides that will kill Varroa are amitraz and formic acid fumes; **(b) Developmental Status:** Amitraz in plastic gives excellent Varroa control, but the manufacturer/distributor (AgrEvo Corp.) has stated that they will not allow amitraz to be marketed to beekeepers because of possible product liability and legal action. Various formulations and application devices for administering formic acid have excellent value in controlling tracheal mites (*Acarapis woodi*), but only limited value against Varroa, especially in hot climates where the bees rear brood and Varroa propagates during all months of the year. Formic acid may have its greatest value in an IPM type of treatment program; **(c) Estimated Time Frame to End-User**: 3-4 years.

- **Constraints to Adoption**: Formic acid may loose its effectiveness in very hot weather.

- **Positive Attributes of Alternative Technology**: Formic acid is a natural product found in honey. Amitraz may not be registered for bee use by the company. However, it is not an organophosphate or carbamate and is least likely to be banned by EPA in the foreseeable future.

- **CRADA in Place/Name of Company:** None. Formic acid is already an ARS patented product.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Warehouse pests such as Indianmeal moth, confused flour beetle, drugstore beetle, rusty grain beetle, other beetle pests; **(b) Commodity:** flour mills, processing plants, food warehouses; **(c) Specific Endangered Pesticides:** malathion, diazinon, dursban, other organophosphate insecticides used as crack and crevice treatments.

- **(a) Key ARS Location(s):** Manhattan, Kansas; **(b) Contact:** Franklin H. Arthur; **(c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** Cyfluthrin (Tempo) is a pyrethroid that is labeled as a general surface treatment; **(b) Developmental Status:** Continued research being done to improve efficacy; **(c) Estimated Time Frame to End-User:** It is available for use as an emulsifiable concentrate or wettable powder.

- **Constraints to Adoption:** Cyfluthrin is more expensive than most of the older organophosphates. Also, it may not kill insects as quickly as diazinon or dursban.

- **Positive Attributes of Alternative Technology:** Cyfluthrin has a lower mammalian toxicity than many of the organophosphates, and the residual efficacy of cyfluthrin is comparable to that of the organophosphates.

- **CRADA in Place/Name of Company:** No formal CRADA, but cooperative work has been undertaken with Gustafson, Inc., Plano, Texas.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Red flour beetle, Indianmeal moth, almond moth**; (b) Commodity:** stored peanuts; **(c) Specific Endangered Pesticides:** malathion, dichlorvos.

- **(a) Key ARS Location(s):** Manhattan, Kansas; **(b) Contact:** Franklin H. Arthur; **(c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** A pyrethroid aerosol, esfenvalerate is a potential candidate to replace dichlorvos as an aerosol application in peanut warehouses; **(b) Developmental Status:** McLaughlin Gormley King Company (MGK) has completed residue studies and has submitted data to the Environmental Protection Agency (EPA); **(c) Estimated Time Frame to End-User:** Registration is anticipated but the date is unknown.

- **Constraints to Adoption:** This chemical has been in the registration process since 1990. Georgia and Alabama had granted a 24-c label, but they were overuled by the EPA because of their interpretation of the residue data. MGK had to repeat the residue study. The regulatory process has been a major constraint to the development and transfer to the end-user of this alternative to dichlorvos.

- **Positive Attributes of Alternative Technology:** More effective at lower application rates than dichlorvos.

- **CRADA in Place/Name of Company:** No formal CRADA, but cooperative work has been undertaken with MGK Company, Minneapolis, Minnesota.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Insects infesting stored wheat such as lesser grain borer, rice weevil, sawtoothed grain beetle, rusty grain beetle, red flour beetle , and other beetle pests. Insect pests of stored corn such as maize weevil, red flour beetle, Angoumois grain moth, other beetle pests; **(b) Commodity:** stored wheat and stored corn**; (c) Specific Endangered Pesticides:** malathion and pirimiphos-methyl (Actellic) on corn.

- **(a) Key ARS Location(s):** Manhattan, Kansas**; (b) Contact:** Franklin H. Arthur**; (c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** Two pyrethroid insecticides, deltamethrin and cyfluthrin **(b) Developmental Status:** Gustafson, Inc. has submitted data for both insecticides to the EPA; **(c) Estimated Time Frame to End-User:** According to Gustafson, Inc., registration is anticipated by the year 2000.

- **Constraints to Adoption:** Regulatory process and the costs of registration. Also, pyrethroids are more expensive to synthesize and develop than organophosphates and the chemicals will cost more to use.

- **Positive Attributes of Alternative Technology:** More effective at lower application rates than organophosphates that are currently registered.

- **CRADA in Place/Name of Company:** No formal CRADA; cooperative work has been undertaken with Gustafson, Inc., Plano, Texas.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Codling moth; **(b) Commodity:** pome fruits, especially pears and apples; **(c) Specific Endangered Pesticides:** Azinphosmethyl

- **(a) Key ARS Location(s):** Wapato, Washington; **(b) Contact:** Carrol Calkins; **(c) CRIS Project Number:** 0500-00044-002-00D (areawide pest management program).

- **(a) Key Alternative Technology:** Pheromone mating disruption; **(b) Developmental Status:** 5-year areawide pest management project initiated in 1994 as a Federal, State, industry partnership involving orchards in Washington, Oregon and California; **(c) Estimated Time Frame to End-User:** Currently being adopted by the end-users, program is completed in 1999.

- **Constraints to Adoption:** Secondary pest problem need addressing at times (e.g. leafrollers, but can use Bt instead of Lorsban). Pheromone dispensers are more labor intensive; best with full participation of producers in the growing region; orchards must be cleared of fruit at end of the season.

- **Positive Attributes of Alternative Technology:** Conserves beneficial organisms, specific for target pest and non-toxic; no waiting period for entry into orchards; environmentally friendly.

- **CRADA in Place/Name of Company:** Technology now commercially available (Pacific Biocontrol, Vancouver, WA; Concep Inc., Bend, OR).

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ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Codling moth and navel orangeworm, peach twig borer and other moth pests such as corn earworm, tobacco budworm, oriental fruit moth, cabbage looper and beet armyworm; **(b) Commodity:** walnuts, almonds, corn, cotton, vegetables, fruits and other field crops; **(c) Specific Endangered Pesticides:** chloropyrifos, methidathion, azinphosmethyl, diazinon, naled, and phosmet.

- **(a) Key ARS Location(s):** Albany, California; **(b) Contact:** Douglas Light and Bruce Campbell; **(c) CRIS Project Number:** 5325-42000-019-00D.

- **(a) Key Alternative Technology:** Enhanced and improved efficacy of pheromonal mating disruption systems by host plant volatile (HPV) synergists; **(b) Developmental Status:** Currently isolating/identifying HPVs and screening for pheromone synergism with certain HPVs and increasing pheromone preference by males from 0.25X to 3X over use of the pheromone alone; **(c) Estimated Time Frame to End-User:** One to two years for patent application and CRADA development; 2 years to field testing as a pheromone synergist in mating disruption trials, and 2-4+ years to registration and usage.

- **Constraints to Adoption:** Additional formulation costs (though putative HPV synergists are inexpensive) and additional cost/time to attain registration of new pheromone - HPV product and commercialization.

- **Positive Attributes of Alternative Technology:** Increased pheromone efficacy, reduction in pheromone response threshold and increased response preference; inexpensive; greater volatility, thus, perhaps greater coverage/active space in orchard/field and reduction in number/cost of formulation release sites.

- **CRADA in Place/Name of Company:** No CRADA in place as yet, but Confidentiality Agreements have been signed with Trece, Inc., Salinas, California.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Orchard and other pests, especially leafhoppers, pear psylla, mites, aphids, leafrollers, thrips, plum curculio, codling moth, Japanese beetle; **(b) Commodity:** orchard and over 50 other crops; **(c) Specific Endangered Pesticides:** methylchlorpyrifos, methylparathion and others at risk.

- **(a) Key ARS Location(s):** Kearneysville, West Virginia; **(b) Contact:** David M. Glen; **(c) CRIS Project Number:** 1931-22000-005-00D and 1931-22000-007-00D.

- **(a) Key Alternative Technology:** Kaolin clay; **(b) Developmental Status:** Research with this non-toxic and inexpensive product began in 1992. Possesses a high repellency property against arthropod pests and plant pathogens. Efficacy and spectrum of activity testing continues, as well as formulation studies for application with standard spray equipment; **(c) Estimated Time Frame to End-User:** Three prototype particles have EPA registration and exemption from tolerance; estimated one to two years to end-user.

- **Constraints to Adoption:** Role in IPM not clear; relatively large bulk is required to treat an acre (25 lbs/100 gallons);whitish coating after application; doesn't kill the target pest, acts only as a barrier.

- **Positive Attributes of Alternative Technology:** Cheap and relatively broad spectrum barrier activity for target pests; non-toxic material and environmentally friendly.

- **CRADA in Place/Name of Company:** Engelhard Corporation, New Jersey.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Soft bodied insects such as silverleaf whitefly, aphids, thrips, mites, pear pysllid, etc.; **(b) Commodity:** ornamentals, vegetables, melons, fiber crops, pome fruits, greenhouse, and horticultural crops; **(c) Specific Endangered Pesticides:** multiple substitute for insecticides such as azinphos-methyl, chlorpyrifos, methomyl, methyl-parathion, carbaryl, and endosulfan.

- **(a) Key ARS Location(s):** Kearneysville, West Virginia; **(b) Contact:** Gary Puterka; **(c) CRIS Project Number:** 1931-22000-007-00D.

- **(a) Key Alternative Technology:** Synthetic sugar esters based on natural sugar esters of Nicotiana species; **(b) Developmental Status:** Spectrum of activity testing continues as well as orchard application technology research; **(c) Estimated Time Frame to End-User:** Registration as been submitted with full registration expected by October 1998; one to two years.

- **Constraints to Adoption:** Multiple applications may be required; maybe two years before commercially available. Role in IPM not clear; low residue activity requiring multiple applications; activity restricted to soft-bodied insects.

- **Positive Attributes of Alternative Technology:** Sugar-ester compounds are very low in toxicity, safe to use, have no harmful residues, are safe to predatory insects, and are effective against hard to control insects such as mites, thrips, whiteflies, pear psylla and aphids.

- **CRADA in Place/Name of Company:** AVA Chemical Ventures, New Hampshire.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Western corn rootworm; Northern corn rootworm; and Mexican corn rootworm; **(b) Commodity:** corn, grain sorghum and soybean; **(c) Specific Endangered Pesticides:** carbaryl, methyl parathion - both used for control of adults; carbofuran, chlorpyrifos, dyfonate, phorate, terbufos - all used for control of larvae.

- **(a) Key ARS Location(s):** Brookings, South Dakota; **(b) Contact:** Laurence Chandler; **(c) CRIS Project Number:** 0500-00044-003-00D (Corn rootworm areawide management program).

- **(a) Key Alternative Technology:** Semiochemical attracticide-bait (SLAM) applied as necessary to host crops on a regional basis as a management tool for adult corn rootworms. **(b) Developmental Status:** The program is in the second year of Phase II operations at five sites across the United States (Illinois/Indiana, Iowa, Kansas, South Dakota, and Texas). The insecticide-bait component of the program is continually being modified. Novel non-chemical agents are being evaluated for use in the baits. **(c) Estimated Time Frame to End-User:** Program completion/technology transfer is expected in the year 2000.

- **Constraints to Adoption:** The corn rootworm areawide management program is dependent upon scouting. This added component to growers production costs could be a major constraint if corn prices remain at low levels. Grower education, however, could offset this hurdle if yearly benefits can be demonstrated.

- **Positive Attributes of Alternative Technology:** The areawide management program uses an environmentally friendly approach to corn rootworm management. Bait applications are made only as needed as opposed to prophylactic soil insecticide treatments. SLAM applications use approximately 90% less active ingredient of insecticide than do typical carbaryl foliar treatments.

- **CRADA in Place/Name of Company:** There are no formal agreements in place at this time with the manufacturer (MicroFlo Co.) for the semiochemical-bait. However, there is a long-standing informal collaboration in place with the company.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Mexican corn rootworm; **(b) Commodity:** corn; **(c) Specific Endangered Pesticides:** carbaryl.

- **(a) Key ARS Location(s):** Texas (in cooperation with Brookings, South Dakota); **(b) Contact:** James R. Coppedge; **(c) CRIS Project Number:** 6202-22000-005-00D and 0500-00044-003-00D.

- **(a) Key Alternative Technology:** "Slam" attract and kill bait; **(b) Developmental Status:** now registered for use; **(c) Estimated Time Frame to End-User:** currently involved in technology transfer to producers and consultants as a part of the ARS areawide pest management program.

- **Constraints to Adoption:** Farmers are used to applying soil insecticides for larvae and have difficulty understanding the concept of killing adults one year to prevent corn rootworm larvae the following year.

- **Positive Attributes of Alternative Technology:** When properly implemented, this pest management approach improves control of the pest and reduces the use of carbamate insecticides by up to 95 percent.

- **CRADA in Place/Name of Company:** CRADA was originally with MicroFlo and BASF; however, the CRADA's are no longer needed since the company has commercialized the technology.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Corn earworm; **(b) Commodity:** corn, cotton and vegetables; **(c) Specific Endangered Pesticides:** carbaryl, methylparathion, and others.

- **(a) Key ARS Location(s):** College Station, Texas; **(b) Contact:** James R. Coppedge; **(c) CRIS Project Number:** 6202-22000-005-00D.

- **(a) Key Alternative Technology:** Attract and kill bait (feeding attractant), long range attractant (volatiles from the guara flower); **(b) Developmental Status:** toxicants have been developed and evaluated, but need to be evaluated on a large area for adult management; **(c) Estimated Time Frame to End-User:** 2-3 years.

- **Constraints to Adoption:** Registration constraints (EPA requires all 11 volatiles in the attractant to be registered); need to attack pest at sites of origin and therefore need buy-in on an areawide basis by all farmers where the insect occurs since it is migratory.

- **Positive Attributes of Alternative Technology:** Could significantly reduce pesticide use to manage this pest and improve yields in cotton, corn, and several other crops; highly specific to target pest; environmentally friendly.

- **CRADA in Place/Name of Company:** CRADA was formerly with BASF; however, the CRADA was not renewed because of registration constraints; EPA requires that all 11 volatiles be registered as pesticides rather than as an attractant.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Cotton fleahopper; **(b) Commodity:** cotton; **(c) Specific Endangered Pesticides:** Orthene, guthion, malathion, carbaryl, dimethoate and others.

- **(a) Key ARS Location(s):** College Station, Texas; **(b) Contact:** James R. Coppedge; **(c) CRIS Project Number:** 6202-22000-005-00D.

- **(a) Key Alternative Technology:** Attract and kill bait; **(b) Developmental Status:** feeding attractant (from Texas croton and horsemint) has been isolated, but not identified and synthesized; **(c) Estimated Time Frame to End-User:** two to three years from development to end-user.

- **Constraints to Adoption:** Efficacy lower than chemical pesticides and cost may be higher. Finding a manufacturer willing to invest in the technology may be difficult.

- **Positive Attributes of Alternative Technology:** Reduce use of organophosphate and carbamate insecticides helps to conserve beneficial insects; specific for target pest, environmentally friendly.

- **CRADA in Place/Name of Company:** None, but negotiating with TRECE, Inc.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Boll weevil; **(b) Commodity:** cotton; **(c) Specific Endangered Pesticides:** malathion.

- **(a) Key ARS Location(s):** College Station and Weslaco, Texas; **(b) Contact:** James R. Coppedge; **(c) CRIS Project Number:** 6202-22000-005-00D and 6204-22000-010-00D.

- **(a) Key Alternative Technology:** Attract and kill bait using long range feeding attractant and photoactive dye; **(b) Developmental Status:** attractants being evaluated for effectiveness; **(c) Estimated Time Frame to End-User:** should be available to producers in three to five years.

- **Constraints to Adoption:** Use of the technology needs to be demonstrated on an areawide basis; commercialization.

- **Positive Attributes of Alternative Technology:** Reduces the use of organophosphate insecticides with the conservation of beneficial insects; highly specific to the target pest.

- **CRADA in Place/Name of Company:** No CRADA's have been developed, but several companies have expressed a keen interest in the technology.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Boll weevil; **(b) Commodity:** cotton; **(c) Specific Endangered Pesticides:** malathion, azinphosmethyl, methyl parathion.

- **(a) Key ARS Location(s):** Weslaco, Texas; **(b) Contact:** Dale Spurgeon; **(c) CRIS Project Number:** 6204-22000-010-00D.

- **(a) Key Alternative Technology:** Boll weevil photoactive dye/bait formulation; **(b) Developmental Status:** A basic bait formulation has been developed that effectively arrests boll weevil adults contacting it. When combined with photoactive dyes (e.g. phloxin B, Rose bengal) this bait/dye formulation has provided complete control in 3-4 hours. In recent greenhouse trials, modifications of the formulation have resulted in 80-100 percent mortality of boll weevils in 24-48 hours. Work is currently in progress to improve the rainfastness/longevity of the bait while maintaining a high level of efficacy. ARS plans to conduct preliminary field assays in the late summer of 1998; **(c) Estimated Time Frame to End-User:** The formulation should be available for field testing within 2 years. Estimated time frame to end-user will depend on projected cost effectiveness of the final formulation, modifications in formulation, or method of use necessary to bring costs to an acceptable level.

- **Constraints to Adoption:** The bait/dye formulation will be most effective and economical in pre-blooming cotton, but the formulation will be incompatible with maturing cotton because of the risks of lint staining. Perception of cost to the end-user could become an issue as could application technology issues. The current formulation can be applied by a conventional sprayer, but future, longer-lasting formulations may require modified application equipment. The formulation could possibly pose a threat to foraging honeybees.

- **Positive Attributes of Alternative Technology:** The bait/dye formulation appears to be highly efficacious against adult boll weevils while being virtually nontoxic to non-target organisms. One of the dyes, phloxin B, is FD&C approved, and thus should pose little or no danger to the environment. Success in developing a formulation that is attractive and effective for more than one week should facilitate an unusually high level of early-season boll weevil control, thereby reducing the need for treatment with chemical pesticides later in the season.

- **CRADA in Place/Name of Company:** A CRADA has been established to develop this product with TRECE, Inc., Salinas, California.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Corn rootworm pest complex **(b) Commodity:** corn, melons and cucumbers **(c) Specific Endangered Pesticides:** carbaryl.

- **(a) Key ARS Location(s):** Beltsville, Maryland (in collaboration with the corn rootworm areawide management program in Brookings, South Dakota); **(b) Contact:** Robert F. Schroder; **(c) CRIS Project Number:** 1275-22000-091-00D.

- **(a) Key Alternative Technology:** D & C Red Dye No. 28 (photoactive dye); **(b) Developmental Status:** EUP requested; field tests proposed in terms of bait efficacy, formulations, and aerial application technology on corn; large scale evaluations of bait planned for Summer of 1998 in Texas and South Dakota; **(c) Estimated Time Frame to End-User:** One to two years.

- **Constraints to Adoption:** Registration still needed; Experimental use permit from EPA was filed, but still needs granting for use of dye in new ARS bait formulation; dye needs to be ingested to be effective.

- **Positive Attributes of Alternative Technology:** Relatively broad spectrum, safe for humans and the environment; should fit with IPM strategies.

- **CRADA in Place/Name of Company:** PhotoDye International, Linthicum, Maryland.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Boll weevil; **(b) Commodity:** cotton; **(c) Specific Endangered Pesticides:** malathion, azinphosmethyl, methyl parathion.

- **(a) Key ARS Location(s):** Weslaco, Texas; **(b) Contact:** Dale Spurgeon; **(c) CRIS Project Number:** 6204-22000-010-00D.

- **(a) Key Alternative Technology:** Improved boll weevil trap; **(b) Developmental Status:** The improved trap has been field tested and is primarily more efficient at capturing weevils, and at retaining captured weevils, than are existing trap designs. Evaluations indicate that the physical characteristics of the new traps result in more than a 23% increase in captures relative to the standard Hercon trap. It is expected that additional modifications (color) will result in further increases in captures. Blow-molded prototypes were recently delivered to the ARS CRADA partner (TRECE, Inc.); **(c) Estimated Time Frame to End-User:** The improved boll weevil trap should be available to the end-user within 2 years.

- **Constraints to Adoption:** Efficacy of a mass trapping strategy in the Boll Weevil Eradication Program (sensitive areas) using the new trap still needs to be evaluated. Also, community-wide non-cropping season mass trapping may be a possibility, but it will need to be further evaluated on a large scale. Cost will likely be higher than for the current commercial Hercon trap.

- **Positive Attributes of Alternative Technology:** Improving trapping efficiency may result in successful use of trapping technology in sensitive areas of the Boll Weevil Eradication Program. The new trap is easier to maintain than existing designs, will incorporate interchangeable parts (which will improve economy of using this trap), and may need to be serviced less frequently than the standard trap, by virtue of its larger trapping capacity.

- **CRADA in Place/Name of Company:** a CRADA with TRECE, Inc., Salinas, California has been established.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Tephridid fruit flies; **(b) Commodity:** citrus and subtropical fruit, deciduous fruit, vegetables; **(c) Specific Endangered Pesticides:** malathion.

- **(a) Key ARS Location(s):** Hilo, Hawaii; Weslaco, Texas; and Miami, Florida; **(b) Contact:** Steve Peck and Robert Mangan; **(c) CRIS Project Number:** 5320-22430-017-00D.

- **(a) Key Alternative Technology:** Spinosad; **(b) Developmental Status:** Field tests being undertaken in terms of formulations, efficacy, and application technology, especially ground application; **(c) Estimated Time Frame to End-User:** intensive evaluations planned for Fall of 1998 in Hawaii.

- **Constraints to Adoption:** None readily apparent.

- **Positive Attributes of Alternative Technology:** Extremely low mammalian toxicity.

- **CRADA in Place/Name of Company:** None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Tephridid fruit flies**; (b) Commodity:** citrus and subtropical fruit, deciduous fruit, vegetables**; (c) Specific Endangered Pesticides:** malathion.

- **(a) Key ARS Location(s):** Hilo,Hawaii; Weslaco, Texas; and Miami, Florida; **(b) Contact:** Steve Peck and Robert Mangan**; (c) CRIS Project Number:** 5320-22430-017-00D.

- **(a) Key Alternative Technology:** SureDye**; (b) Developmental Status:** Testing in progress; **(c) Estimated Time Frame to End-User:** Availability to end-use depends on progress toward EPA registration.

- **Constraints to Adoption:** Concern by State authorities over efficacy and use patterns to minimize staining and phytotoxicity potential in urban areas; needs to be ingested.

- **Positive Attributes of Alternative Technology:** Very low mammalian toxicity.

- **CRADA in Place/Name of Company:** PhotoDye International, Linthicum, Maryland.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Imported fire ant; **(b) Commodity**: agriculture, livestock, and humans; **(c) Specific Endangered Pesticides**: chlorpyrifos and diazinon.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Dave Williams; **(c) CRIS Project Number**: 6615-32000-029-00D.

- **(a) Key Alternative Technology**: Photoactive compounds in a bait matrix for rapid colony decimation; and, highly specific semiochemicals (pheromones) to disrupt social structure of fire ant colonies, or reproductive capacity of queens; **(b) Developmental Status:** evaluations in field tests are underway; **(c) Estimated Time Frame to End-User**: 2-5 years.

- **Constraints to Adoption**: Commercialization by the chemical industry.

- **Positive Attributes of Alternative Technology**: Environmentally-friendly.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Adult house flies; **(b) Commodity**: animals and humans; **(c) Specific Endangered Pesticides**: dimethoate, tetrachlorvinphos, and dichlorvos.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Don Barnard; **(c) CRIS Project Number**: 6615-32000-032-00D.

- **(a) Key Alternative Technology**: Behaviorally-based control methods for adult filth flies (primarily house fly) on agricultural facilities comprising the use of strategically-placed ultra-violet light traps, and QuickStrike fly bait stations, and/or the use of Z9T and related unsaturated hydrocarbons for use in sex pheromone baits against house fly and house fly subspecies; **(b) Developmental Status**: Current field tests of the two control methods indicate 80-90 percent reductions in house fly populations; field test evaluations continue; **(c) Estimated Time Frame to End-User**: 1-5 years.

- **Constraints to Adoption**: Effective placement of traps and bait stations depends on knowledge of the distributional patterns of adult flies in individual houses. This factor must be determined prior to placement of traps and stations. Influence of UV light on egg production in laying hens is currently being evaluated. For fly pheromones, the spectrum of saturated and unsaturated hydrocarbons, including Z-9-tricosene and other volatile and semivolatile compounds in fly cuticle, that can be used for this purpose against house fly and related species of filth flies must be determined. Field testing of pheromones in baits also needs to be undertaken.

- **Positive Attributes of Alternative Technology**: Zero non-target effects, non-pesticidal, and non-polluting.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Adult mosquitoes; **(b) Commodity**: animals and humans; **(c) Specific Endangered Pesticides**: malathion, fenthion, naled, and chlorpyrifos.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Don Barnard; **(c) CRIS Project Number**: 6615-32000-031-00D.

- **(a) Key Alternative Technology**: Mosquito attractants; **(b) Developmental Status:** A number of mosquito attractants and attractant blends have been discovered by ARS scientists in Gainesville. ARS is in the process of developing apparatus for delivering these attractants in the field and for integrating the use of attractants into new designs for adult mosquito traps. Species-specific attractants will be used for improved detection of insect vectors, whereas attractants and mosquito traps can be used together for mosquito control in 'removal trapping' schemes; **(c) Estimated Time Frame to End-User**: 3-5 years.

- **Constraints to Adoption**: Completion of research. The specificity and dose-response range for attractants and attractant blends to different mosquito species still needs to be determined, as well as the range of influence of environmental factors on mosquito responses to attractants under field conditions. Formulation of attractants and attractant blends for release and a determination of the optimal effectiveness under field conditions needs completing. Commercialization by industry.

- **Positive Attributes of Alternative Technology**: Attractants can be made either species-specific or general in action. There are zero non-target effects, and the agents are non-polluting.

- **CRADA in Place/Name of Company:** American Biophysics Company.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Immature and adult mosquitoes; **(b) Commodity**: animals and humans; **(c) Specific Endangered Pesticides**: temephos (larvae), malathion, fenthion, naled, and chlorpyrifos.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Don Barnard; **(c) CRIS Project Number**: 6615-32000-031-00D.

- **(a) Key Alternative Technology**: Synthetic peptide hormones and peptide hormone mimics have been developed that will inhibit blood meal digestion and ovarian development in mosquitoes; **(b) Developmental Status:** Three peptide hormones and 5 peptide hormone mimics have been synthesized thus far and have shown oostatic activity against biting flies. Studies currently underway seek to modify these molecules for enhanced penetration through the insect cuticle as a novel delivery route; **(c) Estimated Time Frame to End-User**: 3-5 years.

- **Constraints to Adoption**: An effective and efficient system for delivery of hormones and hormone mimics to the target site in individual mosquitoes in natural populations in the field; commercial production.

- **Positive Attributes of Alternative Technology**: Species-specific, and non-polluting.

- **CRADA in Place/Name of Company:** None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Adult mosquitoes; **(b) Commodity**: animals and humans; **(c) Specific Endangered Pesticides**: malathion, fenthion, naled, and chlorpyrifos.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Don Barnard; **(c) CRIS Project Number**: 6615-32000-031-00D.

- **(a) Key Alternative Technology**: Adult mosquito traps that utilize 'counterflow' air/attractant stream technology or that produce, utilize, and/or emit heat, carbon dioxide, and/or chemical attractants for adult mosquitoes; **(b) Developmental Status:** Field testing of new trap designs is currently underway; **(c) Estimated Time Frame to End-User**: 1-3 years.

- **Constraints to Adoption**: Initial availability of traps may be limited by the production capacity of the manufacturer and by design changes in the traps as a consequence of new information provided by research.

- **Positive Attributes of Alternative Technology**: Minimum non-target effects, and non-polluting.

- **CRADA in Place/Name of Company:** Biosensory Insect Controls, Inc.; American Biophysics Company.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Bee Varroa mite *Varroa jacobsoni*; **(b) Commodity**: about 90 cultivated crops and honey; **(c) Specific Endangered Pesticides**: pyrethroid fluvalinate (Apistan).

- **(a) Key ARS Location(s)**: Weslaco, Texas. The Weslaco ARS Honey Bee group has begun research on alternative control measures for Varroa. Working in cooperation with Weslaco will be the USDA-ARS Natural Products Unit at Oxford, Mississippi; **(b) Contact**: F. Eischen and P. Elzen; **(c) CRIS Project Number**: 6204-21000-007-00D.

- **(a) Key Alternative Technology**: Natural products from more than 50 plant species; **(b) Developmental Status:** research commenced one year ago; **(c) Estimated Time Frame to End-User**: up to 5 or more years.

- **Constraints to Adoption**: Commercialization by industry.

- **Positive Attributes of Alternative Technology**: Use of natural product compounds to control Varroa commercially is attractive from several different viewpoints. Foremost among these is making available another product to use in rotation with Apistan, now that resistance to Apistan has been documented. The fact that natural product compounds are environmentally safe is also a positive factor. There is widespread industry support for the use of natural products in commercial honey bee operations.

- **CRADA in Place/Name of Company:** None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Parasitic bee mites; **(b) Commodity**: about 90 cultivated crops and honey; **(c) Specific Endangered Pesticides**: Apistan.

- **(a) Key ARS Location(s)**: Weslaco, Texas; **(b) Contact**: William Wilson; **(c) CRIS Project Number**: 6204-21000-007-00D.

- **(a) Key Alternative Technology**: ARS Honey Bee Laboratory in Weslaco and Beltsville are investigating the varroicidal activity of natural products. Natural product compounds are environmentally safe. There is widespread industry support for the use of natural products in commercial honey bee operations; **(b) Developmental Status:** Research initiated one year ago; **(c) Estimated Time Frame to End-User**: up to 5 or more years.

- **Constraints to Adoption**: Industry interest to manufacture and market certain natural products.

- **Positive Attributes of Alternative Technology**: Environmentally-friendly.

- **CRADA in Place/Name of Company:** None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLES

- **(a) Key Target Pest(s):** Warehouse pests such as Indianmeal moth, confused flour beetle, drugstore beetle, rusty grain beetle, other beetle pests; **(b) Commodity:** flour mills, processing plants, food warehouses; **(c) Specific Endangered Pesticides:** malathion, diazinon, dursban, other organophosphate insecticides used as crack and crevice treatments.

- **(a) Key ARS Location(s):** Manhattan, Kansas; **(b) Contact:** Franklin H. Arthur; **(c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** Several formulations of diatomaceous earth;
  (b) Developmental Status: Continued research being done to improve efficacy;
  (c) Estimated Time Frame to End-User: Currently registered for use on flooring surfaces inside warehouses.

- **Constraints to Adoption:** Diatomaceous earth does not kill insects as quickly as conventional insecticides, including the organophosphates that are in danger under the FQPA.

- **Positive Attributes of Alternative Technology:** Diatomaceous earth is a non-toxic method for controlling insects.

- **CRADA in Place/Name of Company:** No formal CRADA, but cooperative work with Hedley Technologies, Mississauga, Ontario.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Insects infesting stored wheat such as lesser grain borer, rice weevil, sawtoothed grain beetle, rusty grain beetle, red flour beetle, and other beetle pests. Insect pests of stored corn such as maize weevil, red flour beetle, Angoumois grain moth, other beetle pests; **(b) Commodity:** stored wheat and stored corn; **(c) Specific Endangered Pesticides:** malathion and pirimiphos-methyl (Actellic) on corn.

- **(a) Key ARS Location(s):** Manhattan, Kansas; **(b) Contact:** Franklin H. Arthur; **(c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** Diatomaceous earth, a non-toxic insecticide that kills insects by damaging the cuticle and causing water loss; **(b) Developmental Status:** Continued research being undertaken to improve efficacy; **(c) Estimated Time Frame to End-User:** Several formulations are now registered for insect control that are more effective than older products.

- **Constraints to Adoption:** Industry is reluctant to use these products. They require more time than conventional chemicals to kill insects. Dusts can cause respiratory problems, alter test weight of the grain, and must be cleaned from the grain. Their efficacy against internal feeders has been questioned. There is variation among dusts as to their effectiveness. These DE products also kill beneficial insects in addition to the pest species.

- **Positive Attributes of Alternative Technology:** A non-toxic method of insect control that does not leave a pesticidal residue on the wheat.

- **CRADA in Place/Name of Company:** No formal CRADA; cooperative work is being undertaken with Hedley Technologies, Mississauga, Ontario.

Potential Alternatives [illegible] Pesticides Threatened [illegible] Implementation of FQPA

(a) Key Target Pest(s): Insects infesting stored wheat such as lesser grain borer, rice weevil, sawtoothed grain beetle, rusty grain beetle, red flour beetle, and other insect pests. Insect pests of stored corn such as maize weevil, red flour beetle, Angoumois grain moth, other [illegible] pests; (b) Commodity: stored wheat and stored corn; (c) Specific Endangered Pesticides: malathion and pirimiphos-methyl (Actellic) on corn

(a) Key ARS Location(s): Manhattan, Kansas; (b) Contact: Franklin H. Arthur; (c) CRIS Project Number: 5430-43000-017-00D

(a) Key Alternative Technology: Diatomaceous earth, a non-toxic insecticide that kills insects by damaging the cuticle and causing water loss; (b) Developmental Status: Continued research being undertaken to improve [illegible]; (c) Estimated Time Frame to End-User: Several formulations are now registered [illegible] insect control that are more effective than older products.

Constraints to Adoption [illegible] reluctant to [illegible] these products. They require more time than conventional [illegible] to kill insects. [illegible] can cause respiratory problems, alter test weight of the grain, and [illegible] readers has been questioned. [illegible] DE products also kill beneficial [illegible]

Positive Attributes of [illegible]: A non-toxic method of insect control that does not leave a [illegible] residue on the wheat

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Insects infesting stored wheat such as lesser grain borer, rice weevil, sawtoothed grain beetle, rusty grain beetle, red flour beetle , and other beetle pests. Insect pests of stored corn such as maize weevil, red flour beetle, Angoumois grain moth, other beetle pests; **(b) Commodity:** stored wheat and stored corn; **(c) Specific Endangered Pesticides:** malathion and pirimiphos-methyl (Actellic) on corn.

- **(a) Key ARS Location(s):** Manhattan, Kansas; **(b) Contact:** Franklin H. Arthur; **(c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** Cooling corn and wheat through low-volume air movement (aeration) can help control insects. The expanded use of aeration can reduce the potential of severe infestations and improve the efficiency of beneficial insects; **(b) Developmental Status:** Continued research being undertaken to improve efficacy; **(c) Estimated Time Frame to End-User:** Many grain storage bins are currently equipped with aeration systems.

- **Constraints to Adoption:** Aeration management plans need to be refined and integrated with insect population models. Persons involved with managing stored grains need to adopt these new methods for using aeration.

- **Positive Attributes of Alternative Technology:** A non-chemical control strategy that preserves the beneficial insects.

- **CRADA in Place/Name of Company:** None, but cooperative areawide pest management project in place with the industry.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLES

- **(a) Key Target Pest(s):** Warehouse pests such as Indianmeal moth, confused flour beetle, drugstore beetle, rusty grain beetle, other beetle pests; **(b) Commodity:** flour mills, processing plants, food warehouses; **(c) Specific Endangered Pesticides:** malathion, diazinon, dursban, other organophosphate insecticides used as crack and crevice treatments.

- **(a) Key ARS Location(s):** Manhattan, Kansas; **(b) Contact:** Franklin H. Arthur; **(c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** Heat treatment, either alone or in combination with diatomaceous earth, to kill insects inside flour mills; **(b) Developmental Status:** Continued research being done to improve efficacy; **(c) Estimated Time Frame to End-User:** Currently available.

- **Constraints to Adoption:** Some areas of processing facilities contain equipment that may be sensitive to heat. Also, the fate of diatomaceous earth in processing facilities is not known at this time.

- **Positive Attributes of Alternative Technology:** This alternative has the potential for greatly reducing pesticide use in flour mills, processing plants and warehouses.

- **CRADA in Place/Name of Company:** No formal CRADAs, but cooperative projects and/or financial support from Quaker Oats Company and Hedley Technologies, Mississauga, Ontario.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLES

- **(a) Key Target Pest(s):** Warehouse pests such as Indianmeal moth, confused flour beetle, drugstore beetle, rusty grain beetle, other beetle pests; **(b) Commodity:** flour mills, processing plants, food warehouses; **(c) Specific Endangered Pesticides:** malathion, diazinon, dursban, other organophosphate insecticides used as crack and crevice treatments.

- **(a) Key ARS Location(s):** Manhattan, Kansas; **(b) Contact:** Franklin H. Arthur; **(c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** Development of resistant packaging and package treatments to prevent insects from entering processed food; **(b) Developmental Status:** Continued research being done to improve efficacy; **(c) Estimated Time Frame to End-User:** Products currently available.

- **Constraints to Adoption:** In some cases, costs of improvements outweigh the benefits.

- **Positive Attributes of Alternative Technology:** This is a non-toxic method of insect control that is effective.

- **CRADA in Place/Name of Company:** Ralston-Purina, St. Louis, Missouri; International Paper, Loveland, Ohio. Trust fund agreement with Continental Extrusion, Cedar Grove, New Jersey.

Selected Examples of Potential Alternatives ARS Program Activities

B. Biological Control Alternatives Research

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Boll weevil; **(b) Commodity:** cotton; **(c) Specific Endangered Pesticides:** malathion.

- **(a) Key ARS Location(s):** Weslaco, Texas and Albany, California; **(b) Contact:** Randy Coleman and Richard Edwards; **(c) CRIS Project Number:** 6204-22000-001-00D and 5325-22410-001-00D.

- **(a) Key Alternative Technology:** *Catolaccus grandis*, a parasite of boll weevil; **(b) Developmental Status:** new artificial diet for rearing the parasite economically has been developed for mass rearing and use of the parasite for augmentation biocontrol purposes. Two companies are being considered as possibilities for scale-up production; **(c) Estimated Time Frame to End-User:** Two to three years.

- **Constraints to Adoption:** When and how to use *Catolaccus grandis* under differing geographical and climatic situations needs to be clarified. The most effective release strategies and rates of release need to be better delineated. The operational means and capacity for achieving mass propagation, packaging, mass transport and mass release is still to be addressed. Economic costs for the end-user will depend on efficient production.

- **Positive Attributes of Alternative Technology:** Substitute for malathion in environmental sensitive areas as a part of the Boll Weevil Eradication Program. Scale-up and use of *C. grandis* has potential as a substitute for malathion in an areawide program that incorporates cultural practices.

- **CRADA in Place/Name of Company:** Integrated Biocontrol Systems, Inc., Aurora, Indiana.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Russian wheat aphid (*Diuraphis noxia*), greenbug (*Schizaphis graminum*), bird cherry-oat aphid (*Rhopalosiphum padi*), corn leaf aphid (*Rhopalosiphum maidis*), yellow sugarcane aphid (*Sipha flava*), wheatgrass aphid (*Sipha elegans*); **(b) Commodity**: wheat, barley, sorghum; **(c) Specific Endangered Pesticides**: chlorpyrifos, diazinon, dimethoate, disulfoton, malathion, methyl parathion.

- **(a) Key ARS Location(s)**: Stillwater, Oklahoma; **(b) Contact**: John D. Burd; **(c) CRIS Project Number**: 6217-22000-007-00D.

- **(a) Key Alternative Technology**: Classical biological control; **(b) Developmental Status**: Aphid natural enemies collected from various locations through the world (1988-1995) and released throughout the cereal production region of the western United States; **(c) Estimated Time Frame to End-User**: Several species of exotic natural enemies have been established and are now considered an important component in IPM strategies for controlling cereal aphids.

- **Constraints to Adoption**: Growers must adopt IPM strategies that promote the judicious use of insecticides.

- **Positive Attributes of Alternative Technology**: Established natural enemies have no economic cost and can contribute considerably to the overall reduction in the reliance of insecticides to control aphid pests of cereals.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Russian wheat aphid (*Diuraphis noxia*); **(b) Commodity**: wheat, barley, sorghum; **(c) Specific Endangered Pesticides**: chlorpyrifos, diazinon, dimethoate, disulfoton, malathion, methyl parathion.

- **(a) Key ARS Location(s)**: Stillwater, Oklahoma; **(b) Contact**: Norman C. Elliott; **(c) CRIS Project Number**: 6217-22000-008-00D.

- **(a) Key Alternative Technology**: Classical biological control; **(b) Developmental Status**: Two exotic parasitoid species (*Aphelinus asychis* and *A. albipodus*) were released in 1991 through 1994 and were found to have been established in 1994. It is too early to evaluate their ultimate impact, but information to date suggests that they will be components of an overall IPM strategy rather than exerting complete control. Releases of additional natural enemies against the Russian wheat aphid and other cereal aphids are ongoing; **(c) Estimated Time Frame to End-User**: Already delivered.

- **Constraints to Adoption**: Heavy insecticide use and lack of diversity in cropping systems at a landscape scale are believed to limit the effectiveness of these parasitoids.

- **Positive Attributes of Alternative Technology**: The positive attributes of classical biological control are well known and include reduced reliance on chemical insecticides and increased grower profits.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: European corn borer, *Ostrinia nubilalis*; **(b) Commodity**: corn; **(c) Specific Endangered Pesticides**: Lorsban, liquid Furadan, methyl parathion, and Sevin.

- **(a) Key ARS Location(s)**: Ames, Iowa; **(b) Contact**: Les Lewis; **(c) CRIS Project Number**: 3625-22000-013-00D.

- **(a) Key Alternative Technology**: Trichocaps--a commercial preparation of *Trichogramma brassicae*, an egg parasitoid; **(b) Developmental Status**: Three years of field testing have been completed; **(c) Estimated Time Frame to End-User**: At least two additional years are needed to develop release strategies.

- **Constraints to Adoption**: Cost--currently produced in Valbonne, France. Availability in the U.S.

- **Positive Attributes of Alternative Technology**: Only one release per year required. No need for chemical insecticides.

- **CRADA in Place/Name of Company**: No formal agreements--interact extensively with Biotop, Valbonne, France.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: European corn borer, *Ostrinia nubilalis* (Hubner), and other lepidopterous pests; **(b) Commodity**: corn; **(c) Specific Endangered Pesticides**: liquid Furadan, methyl parathion, Sevin.

- **(a) Key ARS Location(s)**: Mississippi State, Mississippi; **(b) Contact**: Donald Nordlund; **(c) CRIS Project Number**: 6406-22000-018-00D.

- **(a) Key Alternative Technology**: Development of an artificial diet based automated mass rearing system for *Trichogramma* spp.; **(b) Developmental Status**: The combination of artificial diet and automation will significantly reduce production costs, increase production capacity, and result in improved parasitoid quality. The model system has been designed, and, with recent improved understanding of *Trichogramma* larval feeding behavior, improvements in the artificial diet are imminent; **(c) Estimated Time Frame to End-User**: Technology will be ready to transfer to private sector insectaries in 2-3 years.

- **Constraints to Adoption**: Wide use of *Trichogramma* spp. for control of lepidopterous insects is constrained by their relatively high costs, limited production capacity, and variability in parasitoid quality. This situation has also limited our ability to conduct large scale tests of efficacy, though these insects are the most widely used insect biological control agents in the world. The successful development of an artificial diet-based automated mass rearing system will significantly reduce or eliminate these constraints.

- **Positive Attributes of Alternative Technology**: Use of biological control agents eliminates the risks associated with development of resistance and pest resurgence, induction of secondary pest outbreaks, and environmental polution.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: *Lygus* bugs (2 spp.); **(b) Commodity**: strawberries; **(c) Specific Endangered Pesticides**: malathion, naled.

- **(a) Key ARS Location(s)**: Newark, Delaware; **(b) Contact**: Roger W. Fuester; **(c) CRIS Project Number**: 1926-22000-006-00D.

- **(a) Key Alternative Technology**: Biological control of *Lygus* bugs on strawberries; **(b) Developmental Status**: An European parasite (*Peristenus digoneutis* has been established in alfalfa, in the Northeast U.S. Once its effectiveness was verified, research was begun on strawberries to learn if this parasite will provide adequate biocontrol in this crop; **(c) Estimated Time Frame to End-User**: Research should be finalized in 4 years (2001).

- **Constraints to Adoption**: Additional research needed on the effectiveness of the parasite on other crops (apples, seed crops, beans, raspberries).

- **Positive Attributes of Alternative Technology**: The introduced European parasite has controlled *Lygus lineolaris* on alfalfa. If the parasite is effective on other crops, significant reductions in insecticide use can occur.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: *Lygus* bugs; **(b) Commodity**: cotton, various seed crops (carrots, alfalfa), strawberries; (c) **Specific Endangered Pesticides**: malathion, naled.

- **(a) Key ARS Location(s)**: Mississippi State, Mississippi; **(b) Contact**: Donald Nordlund; **(c) CRIS Project Number**: 6406-22000-018-00D.

- **(a) Key Alternative Technology**: Artificial diet-based rearing of *Lygus* bugs so that parasites and predators of these pests can be reared; **(b) Developmental Status**: Key parasites and predators have been identified. Artificial diet has been developed for *Lygus* and for at least one of its major predators; **(c) Estimated Time Frame to End-User**: About 3 years of continued research and testing will be required to get these biocontrol agents into practice by end-users.

- **Constraints to Adoption**: Rearing technology has not been perfected for *Lygus* or its predators and parasites. Field release methodologies will also require improvement. End-users, especially those involved in cotton production, will need to be educated about the use of alternatives to pesticides such as natural enemies of *Lygus* bugs.

- **Positive Attributes of Alternative Technology**: The technology is safe (it does not contaminate soils, groundwater, or food suplies). It can be a very inexpensive technology, if large scale, automated technologies can be applied to production of the natural enemies.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: *Heliothis* and other moth larvae, bettle larvae (such as Colorado potato beetle), aphids, whiteflies, and scales; **(b) Commodity**: potatoes, cotton, vegetables; **(c) Specific Endangered Pesticides**: malathion.

- **(a) Key ARS Location(s)**: Mississippi State, Mississippi; **(b) Contact**: Donald Nordlund; **(c) CRIS Project Number**: 6406-22000-018-00D.

- **(a) Key Alternative Technology**: Artificial diets have been developed and fully tested for lacewings and big-eyed bugs, both generalist predators that are highly touted in agricultural systems; **(b) Developmental Status**: Lacewings are already produced commercially and represent millions of dollars in sales. However, the expense of producing these predators on their natural prey has greatly elevated their costs and limited their use to small settings with high cash value (greenhouses and high cash crops such as strawberries); **(c) Estimated Time Frame to End-User**: Technology for mass rearing could take 1-2 years.

- **Constraints to Adoption**: Some automation for rearing technology has not been perfected or fully developed. Field release methodologies will also require improvement. End-users, especially those involved in cotton production, will need to be educated about the use of alternatives to pesticides such as natural enemies of the target pests.

- **Positive Attributes of Alternative Technology**: The technology is safe (it does not contaminate soils, groundwater, or food supplies). It can be a very inexpensive technology, if large scale, automated technologies can be applied to production of the natural enemies.

- **CRADA in Place/Name of Company**: Beneficial Insectary.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Beet armyworm (BAW); **(b) Commodity**: greenhouse vegetables; **(c) Specific Endangered Pesticides**: malathion.

- **(a) Key ARS Location(s)**: Mississippi State, Mississippi; **(b) Contact**: Donald Nordlund; **(c) CRIS Project Number**: 6406-22000-018-00D.

- **(a) Key Alternative Technology**: Development of a form-fill-seal machine system for in vivo rearing of *Cotesia marginiventris*, a larval parasitoid of BAW; **(b) Developmental Status**: Preliminary tests have been successfully conducted and show promise; **(c) Estimated Time Frame to End-User**: Perfection of a pupal harvesting technique will be required and could take 1-2 years.

- **Constraints to Adoption**: Use of *Cotesia marginiventris* is constrained by the high cost and limited capacity of current in vivo rearing systems. Use of a form-fill-seal machine system will significantly reduce labor requirements and increase capacity. This will make possible adoption of this parasitoid, in high value greenhouse crop systems, practical.

- **Positive Attributes of Alternative Technology**: Use of biological control agents eliminates the risks associated with development of resistance and pest resurgence, induction of secondary pest outbreaks, and environmental pollution.

- **CRADA in Place/Name of Company**: BioBest USA, Inc.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Greenbug (*Schizaphis graminum*) **(b) Commodity**: wheat, barley, sorghum; **(c) Specific Endangered Pesticides**: chlorpyrifos, diazinon, disulfoton, malathion, methyl parathion.

- **(a) Key ARS Location(s)**: Stillwater, Okalhoma; **(b) Contact**: Norman C. Elliott; **(c) CRIS Project Number**: 6217-22000-008-00D.

- **(a) Key Alternative Technology**: Comprehensive technology/program for greenbug IPM; **(b) Developmental Status**: Development of efficient population sampling methods for the greenbug is completed. Research on developing economic thresholds for the greenbug is in its fourth year. Research on estimating the impact of natural enemies on greenbugs is close to completion. Two grants were recently funded to permit development of: (1) thresholds for greenbug natural enemies, and (2) a comprehensive computer-based decision support system for greenbug IPM; **(c) Estimated Time Frame to End-User**: We anticipate it will take four years to deliver the entire package.

- **Constraints to Adoption**: Education of potential end-users will slow adoption.

- **Positive Attributes of Alternative Technology**: The positive attributes of classical biological control are well known and include reduced reliance on chemical insecticides, increased grower profits, and safe for non-target organisms.

- **CRADA in Place/Name of Company**: "Development of a Greenbug IPM Decision Support System for Wheat," with USDA-ARS, Site Specific Technologies, Inc., Stillwater, Oklahoma, and Oklahoma State University.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Subterranean termites, native termites (*Reticulitermes flavipes*, *R. virginicus*, and many others), imported termites (Formosan subterranean termite, *Copotermes formosanus*); **(b) Commodity**: wood; **(c) Specific Endangered Pesticides**: Diazinon.

- **(a) Key ARS Location(s)**: Stoneville, Mississippi, and Mississippi State, Mississippi; **(b) Contact**: Donald Nordlund; **(c) CRIS Project Number**: 6435-32000-001-00D.

- **(a) Key Alternative Technology**: Use of mass-reared natural enemies against pest populations of subterranean termites; **(b) Developmental Status**: Few biological control agents are known, so exploration in China will be conducted where the pest is indigenous. Organisms (parasites, predators, pathogens) will be imported to the quarantine facility for screening. Promising beneficial organisms will be mass reared for field tests that will be conducted where Formosan subterranean termite is a pest. This program is under development, and shipments are expected from China early in 1999; **(c) Estimated Time Frame to End-User**: Screening and preliminary tests will take about two years to complete. Then, decisions will be made on any upscaling of rearing and pest management methods.

- **Constraints to Adoption**: Constraints expected include 1) high cost of rearing natural enemies, and 2) acceptance of biological control methods since effect is not felt immediately, but over a longer term. Chemicals that have been used for many years generally give immediate control.

- **Positive Attributes of Alternative Technology**: Safe for the environment and self-propagating. Once biological control is implemented, natural enemy populations will be supported by pest populations in the field, continual mass propagation in the laboratory for field release may not be required. Natural enemies specific to imported termites should not affect natural decomposition of woody debris in forests by native termites.

- **CRADA in Place/Name of Company**: None.

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... ides Threatened ...

vegetation, and many others), imported ... sites (Formosan subterranean termite *Coptotermes*) ... ; wood ... pest ... dangered ... Etrahon.

(a) Key ARS Location(s): Stoneville, Mississippi, and Mississippi State, Mississippi; (b) Contact: Donald Nordlund; (c) CRIS Project Number: 6435-32000-001-00D.

(a) Key Alternative Technology: Use of mass-reared natural enemies against pest populations of subterranean termites; (b) Developmental Status: Few biological control agents are known, so exploration in China will be conducted where the pest is indigenous. ... anisms (parasites, predators, pathogens) will be imported to the quarantine facility for screening. Promising beneficial organisms will be mass-reared for field tests that will be conducted where Formosan subterranean termite is a pest. This program is under development, and shipments are expected from China early in 1995; (c) Estimated Time Frame to Field Use: Screening and preliminary tests will take about one year to complete. Then, decisions will be made on any upscaling of rearing techniques ... current methods.

Constraints to Adoption: ... expected include 1) high cost of rearing natural ... control methods ... not fall ... ely.

... been used for many years generally give

... e Technology ... al for the environment ... (use biological control is implem... ... ... pest populations in the field, co... ... may not be required. Natural ... decomposition of ... woody debris ... ative termites.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Adult and immature house and stable flies; **(b) Commodity**: animals and humans; **(c) Specific Endangered Pesticides**: dimethoate, tetrachlorvinphos, and dichlorvos.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Don Barnard; **(c) CRIS Project Number**: 6615-32000-032-00D.

- **(a) Key Alternative Technology**: Biologically-based control methods for immature filth flies comprising the use of larval and pupal parasitoids and facultative fly larvae predators; **(b) Developmental Status:** Field tests are underway on a variety of agricultural facilities using augmentative releases of indigenous parasitoids and predators indicate sustained 40-60% reductions in house fly populations; **(c) Estimated Time Frame to End-User**: 1-2 years.

- **Constraints to Adoption**: Completion of research and industry commercialization. Release rates for parasitoids and predators, as well as components of the host-finding process used by these insects, need to be elucidated. For the greatest efficiency of control, the release rates of parasites/predators must be linked to the population density of the target fly population. Accurate estimation techniques for this process need to be developed.

- **Positive Attributes of Alternative Technology**: Many filth fly biological control agents presently are mass-produced and commercially available, host specific, there is zero non-target effects, and the agents are non-polluting.

- **CRADA in Place/Name of Company:** None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Insects infesting stored wheat such as lesser grain borer, rice weevil, sawtoothed grain beetle, rusty grain beetle, red flour beetle , and other beetle pests. Insect pests of stored corn such as maize weevil, red flour beetle, Angoumois grain moth, other beetle pests; **(b) Commodity:** stored wheat and stored corn; **(c) Specific Endangered Pesticides:** malathion and pirimiphos-methyl (Actellic) on corn.

- **(a) Key ARS Location(s):** Manhattan, Kansas; **(b) Contact:** Franklin H. Arthur; **(c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** Improved strategies for using biological controls. Parasites and predators of pest insects, fungal pathogens, insect viruses, and microbial products can reduce insect pest populations; **(b) Developmental Status:** Continued research being undertaken to improve efficacy; **(c) Estimated Time Frame to End-User:** There are firms currently in the private sector that supply beneficial insects for agricultural systems, including stored products.

- **Constraints to Adoption:** Cost of biological controls is often far more expensive than conventional chemicals. Many control agents are specific for a single insect species, and in many field situations, several pest species can cause economic damage. There are also difficulties in obtaining sufficient numbers of biological controls to suppress pest populations..

- **Positive Attributes of Alternative Technology:** Non-chemical control, safe and acceptable to consumers.

- **CRADA in Place/Name of Company:** No formal CRADA; cooperative work is being undertaken with Biofac, Inc., Mathis, Texas.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: European corn borer, *Ostrinia nubilalis*; **(b) Commodity**: corn; **(c) Specific Endangered Pesticides**: liquid Furadan, Lorsban, Sevin, methyl parathion.

- **(a) Key ARS Location(s)**: Ames, Iowa; **(b) Contact**: Les Lewis; **(c) CRIS Project Number**: 3625-22000-013-00D.

- **(a) Key Alternative Technology**: *Bacillus thuringiensis* transgenic corn; **(b) Developmental Status**: 10% of corn acreage planted to B.t. corn in 1998; **(c) Estimated Time Frame to End-User**: Expected acres planted to B.t. corn to increase substantially until over 50% of the acres will be planted to B.t. corn by the year 2000.

- **Constraints to Adoption**: Availability of seed. Grower acceptance of new technology. Cost to grower.

- **Positive Attributes of Alternative Technology**: Eliminate need for rescue treatments with chemical insecticides.

- **CRADA in Place/Name of Company**: Novartis Seed Company--Reimbursable Grant. Also, interacting with all seed corn companies that product B.t. transgenic corn hybrids.

(a) Crop Target: [illegible] corn; [illegible] (b) [illegible] corn [illegible]
(c) Specific [illegible] and [illegible] by [illegible] Sevin, methyl parathion.

(a) ARS Location(s): Ames, Iowa; (b) Contact: Les Lewis
(c) CRIS Project Number: 3625-22000-015-00D.

(a) Key Alternative Technology: [illegible] during whorl stage grain corn; (b) Developmental Status: 10% of corn acreage planted to B.t. corn in 1998; (c) Estimated Time Frame to End-User: Expected acres planted to B.t. corn to increase substantially until over 50% of the acres will be planted to B.t. corn by the year 2000

Constraints to Adoption: Availability of seed. Grower acceptance of new technology. Cost to grower.

Attributes of Alternative Technology: Eliminate need for rescue treatments with chemical insecticides.

CRADA in place/Name of company: Novartis Seed Company–[illegible] Grant No. [illegible] that product B.t. transgenic corn hybrids.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **Key Target Pest(s)**: Horn flies (and potentially other dung-breeding flies); **(b) Commodity**: cattle; **(c) Specific Endangered Pesticides**: coumaphos, diazinon, chlorpyrifos, malathion, dichlorvos, dioxathion, and stirofos.

- **(a) Key ARS Location(s)**: Kerrville, Texas; **(b) Contact**: Sidney Kunz; **(c) CRIS Project Number**: 6205-32000-017-00D.

- **(a) Key Alternative Technology**: Recombinant protein toxin from an entomopathogen that may be larvicidal to horn flies and other dung-breeding flies; **(b) Developmental Status:** Currently, in early developmental stages; **(c) Estimated Time Frame to End-User**: Availability may not be for as long as 7 years.

- **Constraints to Adoption**: Would require construction, registration and licensing of recombinant host producing the larvicidal toxin for delivery to the bovine dung. Alternative hosts envisioned are ruminant microbes or forage plants.

- **Positive Attributes of Alternative Technology**: Would utilize "naturally occurring" toxin for insect control. *Bacillus thuringiensis* has a long history of safe application to forests, vegetables, and aquatic environments and is safe both to personnel and the environment. The toxin is target-specific in its natural form, requiring alkaline proteolytic activation and the presence of a specific receptor in the gut of the target organism.

- **CRADA in Place/Name of Company:** No current CRADA, but there is potential.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Fungal plant pathogens; **(b) Commodity**: vegetables; **(c) Specific Endangered Pesticides**: methasulfocarb, mancozeb, Ferbam, Ziram, Zineb, Polyram, propamocarb.

- **(a) Key ARS Location(s)**: Beltsville, Maryland; **(b) Contact**: Robert D. Lumsden; **(c) CRIS Project Number**: 1275-22000-117-00D.

- **(a) Key Alternative Technology**: Microbial biological control agents; **(b) Developmental Status**: Research is currently ongoing; **(c) Estimated Time Frame to End-User**: 2-5 year development time.

- **Constraints to Adoption**: In early stages of development and will require EPA registration.

- **Positive Attributes of Alternative Technology**: Environmentally safe and potentially economical.

- **CRADA in Place/Name of Company**: None, but there is a trust fund agreement with Thermo Trilogy Corp., Columbia, Maryland, and T. J. Enterprises, Buffalo, South Dakota.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Cotton bollworm/tobacco budworm; **(b) Commodity**: cotton in the Mississippi Delta; **(c) Specific Endangered Pesticides**: acephate, profenofos, and sulprofos alone and in mixtures with other groups of pesticides.

- **(a) Key ARS Location(s)**: Stoneville, Mississippi; **(b) Contact**: Dick Hardee; **(c) CRIS Project Number**: 6401-22000-017-00D.

- **(a) Key Alternative Technology**: Commercially available baculovirus; **(b) Developmental Status**: Research with this specific pathogen for bollworm/budworm began in 1988. Aerial broadcast early in spring over wide areas kills bollworm/budworm larvae on wild host plants before they migrate as moths to cotton; **(c) Estimated Time Frame to End-User**: Product and technology available for use now.

- **Constraints to Adoption**: Cost per cotton acre for broadcast applications are borderline prohibitive. Target pests currently being managed in many areas of U.S. Cotton Belt with B.t. cotton.

- **Positive Attributes of Alternative Technology**: Specific for target pests; no effect on beneficial insects, catfish, wildlife or people; reduces secondary pest outbreaks.

- **CRADA in Place/Name of Company**: None--technology available.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Heliothine and armyworm complexes; **(b) Commodity**: cotton, vegetables and field corn; **(c) Specific Endangered Pesticides**: malathion.

- **(a) Key ARS Location(s)**: Peoria, Illinois; **(b) Contact**: Michael R. McGuire; **(c) CRIS Project Number**: 3260-41000-070-00D.

- **(a) Key Alternative Technology**: New formulations for baculoviruses to enhance user acceptance; **(b) Developmental Status**: Patents in place, negotiations with a company are in progress to license; **(c) Estimated Time Frame to End-User**: If licensed, time frame to end user (producer) could be the summer of 1999.

- **Constraints to Adoption**: Costs of ingredients, scale-up costs, and thus the cost of the end product.

- **Positive Attributes of Alternative Technology**: Formulations suspend well and are easy to mix and apply, environmentally friendly, pest target specific.

- **CRADA in Place/Name of Company**: Negotiations are in progress with Thermo-Trilogy.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Black cutworm, *Agrotis ipsilon*; **(b) Commodity**: corn; **(c) Specific Endangered Pesticides**: liquid Furadan, Lorsban, Sevin, methyl parathion.

- **(a) Key ARS Location(s)**: Ames, Iowa; **(b) Contact**: Les Lewis;
  (c) CRIS Project Number: 3625-22000-013-00D.

- **(a) Key Alternative Technology**: Nuclear polyhedrosis virus; **(b) Developmental Status**: Investigations are underway; **(c) Estimated Time Frame to End-User**: At least five years needed to do research and development.

- **Constraints to Adoption**: Lack of availability of technology.

- **Positive Attributes of Alternative Technology**: Reduce application of soil insecticides. Could be used in areawide management of corn insects.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: *Culex nigripalpus* and *Culex quinquefasciatus* in agricultural and wastewater impoundments; **(b) Commodity**: animals and humans; **(c) Specific Endangered Pesticides**: temephos.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Don Barnard; **(c) CRIS Project Number**: 6615-32000-031-00D.

- **(a) Key Alternative Technology**: ARS currently has in culture a baculovirus that causes severe epizootics in the mosquito vector of St. Louis encephalitis and which is deadly to the northern house mosquito. The chemical activators required for transmission of the virus in mosquitoes is known and ARS can produce the quantities of the virus needed for research; **(b) Developmental Status:** ARS is working with cooperators to develop formulations of the virus and the virus activator for lab and field testing and ARS is in the process of sequencing the genome of the virus. In addition, ARS is searching for other mosquito baculoviruses that infect *Aedes*, *Anopheles*, and *Culex* mosquito species; **(c) Estimated Time Frame to End-User**: 3-5 years.

- **Constraints to Adoption**: Mass production (cell culture) methods for the virus and effective formulations of virus for field application; commercialization.

- **Positive Attributes of Alternative Technology**: non-polluting, safe for most invertebrates, and safe for vertebrates.

- **CRADA in Place/Name of Company:** None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Silverleaf whitefly, pepper weevil, thrips; **(b) Commodity**: vegetables and melons; **(c) Specific Endangered Pesticides**: Oxamyl, diazinon, azinphos-methyl, methyl-parathion, acephate.

- **(a) Key ARS Location(s)**: Weslaco, Texas; **(b) Contact**: Ashok K. Raina; **(c) CRIS Project Number**: 5442-22000-011-00D.

- **(a) Key Alternative Technology**: Mycotrol (*Beauveria bassiana*); **(b) Developmental Status**: Research is complete through registration; **(c) Estimated Time Frame to End-User**: Currently available, other non-commercialized entomopathogenic fungi should be available in 3 years.

- **Constraints to Adoption**: *Beauveria bassiana* has a short life in the field (low persistence) and is affected by weather and application conditions. Cost is higher than that of chemicals now being used.

- **Positive Attributes of Alternative Technology**: Highly specific to insects, few non-target effects, environmentally friendly.

- **CRADA in Place/Name of Company**: CRADA in place, and new agreement is being negotiated with Mycotech Corp., Butte, Montana.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Whitefly; **(b) Commodity**: cotton; **(c) Specific Endangered Pesticides**: Diazinon.

- **(a) Key ARS Location(s)**: Peoria, Illinois; **(b) Contact**: Michael R. McGuire; **(c) CRIS Project Number**: 3260-41000-070-00D.

- **(a) Key Alternative Technology**: *Paculomyces fumosoroseus* is a fungus with activity against whiteflies and other insects; **(b) Developmental Status**: Liquid culture production will enable mass production of this fungus. Culture conditions have been established; **(c) Estimated Time Frame to End-User**: Technology currently available.

- **Constraints to Adoption**: Scale-up cost and possible cost of end product.

- **Positive Attributes of Alternative Technology**: Fungus is selective and safe. Liquid culture should enable cost-effective production of stable spores, environmentally friendly, and pest target relatively specific.

- **CRADA in Place/Name of Company**: EcoSoil, Inc.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: European corn borer, *Ostrinia nubilalis*; **(b) Commodity**: corn; **(c) Specific Endangered Pesticides**: liquid Furadan, methyl parathion, Lorsban and Sevin.

- **(a) Key ARS Location(s)**: Ames, Iowa; **(b) Contact**: Les Lewis; **(c) CRIS Project Number**: 3625-22000-013-00D.

- **(a) Key Alternative Technology**: *Beauveria bassiana* as an endophyte provides season long control of the European corn borer; **(b) Developmental Status**: Commercial production and formulation is underway; **(c) Estimated Time Frame to End-User**: Available to end-user in 2-5 years.

- **Constraints to Adoption**: Availability and acceptable efficacy.

- **Positive Attributes of Alternative Technology**: Potential for sustainability available to growers that elect not to pay increased costs of B.t. transgenic corn seed.

- **CRADA in Place/Name of Company**: Mycogen Company, Huxley, Iowa; and Mycotech Corp., Butte, Montana.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Diamondback moth; **(b) Commodity**: cole crops including broccoli, cauliflower, brussel sprouts, and cabbage; **(b) Specific Endangered Pesticides**: methomyl, azinphos-methyl, acephate.

- **(a) Key ARS Location(s)**: Ithaca, New York; **(b) Contact**: Stephen P. Wraight; **(c) CRIS Project Number**: 1907-22000-010-00D.

- **(a) Key Alternative Technology**: *Beauveria bassiana* based mycoinsecticides; **(b) Developmental Status**: EPA registered products based on strain GHA are now available to end-users. Several small-scale field evaluations have been completed and additional trials are in progress. Results have not been encouraging, as the dose required for control is not economically competitive. Laboratory assays indicate that the virulence of strain GHA against diamondback moth and other Lepidoptera spp. is not exceptional. Consequently, a research and development project (CRADA) is being initiated in Ithaca, New York, to identify new strains of *Beauveria bassiana* with greater virulence against diamondback moth and other lepidopteran pests; **(c) Estimated Time Frame to End-User**: Identification, development, and registration of new Lepidoptera-active strains will require approximately three years.

- **Constraints to Adoption**: Best efficacy is against early-instar larvae; thus careful timing and multiple, frequent applications (at 4-5 day intervals) are required to achieve control. Large numbers of spores must contact the host to insure a high probability of infection under field conditions, and thus, thorough spray coverage of leaf undersides is essential. Achieving effective coverage becomes increasingly difficult as crops mature and foliage density increases. Multiple, frequent applications with highly efficient application equipment is economically feasible in greenhouse systems producing high yields and high-value crops; however, experience gained from developing *Beauveria bassiana* for whitefly control indicates that product and application costs will be the primary constraints for use in field crops.

- **Positive Attributes of Alternative Technology**: *Beauveria bassiana* is a biological control agent which does not accumulate in food chains or otherwise pose any known threat to the environment. Repeated applications at high rates under field conditions have been shown to have minimal impact on beneficial insects including honey bees and many natural enemies of various pest species. Resistance to *Beauveria bassiana* has not been observed in pest populations and is expected to develop extremely slowly or not at all. The U.S. EPA has exempted *Beauveria bassiana* strain GHA from the requirement for residue tolerances in all

raw agricultural commodities. There is therefore no preharvest interval, and the restricted entry interval is only 12 hours. *Beauveria bassiana* is a good candidate for many IPM systems, because it is fully compatible (can be tank-mixed) with most chemical insecticides.

- **CRADA in Place/Name of Company**: Ithaca, New York, Mycotech Corp., Butte, Montana, (CRADA written by Mycotech Corp. and ARS-Ithaca is submitted for ARS approval).

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: European corn borer, corn earworm, fall armyworm; **(b) Commodity**: field corn, sweet corn; **(c) Specific Endangered Pesticides**: carbofuran, methomyl, methyl parathion, chlorpyrifos, thiodicarb, carbaryl.

- **(a) Key ARS Location(s)**: Ithaca, New York; **(b) Contact**: Stephen P. Wraight; **(c) CRIS Project Number**: 1907-22000-010-00D.

- **(a) Key Alternative Technology**: *Beauveria bassiana* based mycoinsecticides; **(b) Developmental Status**: Studies conducted in France during the mid 1980s resulted in development and registration in that country of a *Beauveria bassiana* based mycoinsecticide for control of the corn borer. Trials have shown this product to be as efficacious as chemical insecticides (see Labatte et. al. 1966, J. Econ. Entomol. 89: 852-862); however, adoption remains limited. Laboratory assays and preliminary field evaluations indicated that the GHA strain of *Beauveria bassiana* developed in the U.S. is relatively ineffective against European corn borer. Bioassays have now identified numerous isolates with substantially greater virulence against this key pest. Assays are in progress to identify one or more of these isolates with exceptional virulence against the other two pests, and initial screening of selected candidates under field conditions is planned for August 1998. Control strategies and application methods are under development; **(c) Estimated Time Frame to End-User**: The estimated time frame to end-user is approximately three years.

- **Constraints to Adoption**: Corn borers and corn earworms are cryptic during much of their development, making them extremely difficult targets for fungal pathogens. A narrow window exists for applications targeting the small instars feeding in the whorls prior to their boring into the plant. This beneficial fungus cannot be tank-mixed or applied on the same day as many of the chemical fungicides commonly used for plant-disease control. Field corn is a relatively low-value crop that cannot support high-cost control measures.

- **Positive Attributes of Alternative Technology**: The whorls of corn plants form natural catch basins for materials applied from directly overhead. The fungus spores can thus be delivered in various ways including as liquid sprays or dry granules, or in irrigation water. Applied spores tend to become concentrated in the base of the whorl, precisely where the young larvae begin feeding. The microclimate of the leaf whorl is sufficiently humid to support not only fungal germination and host infection, but also fungal growth and sporulation on a granular substrate with incorporated nutrients. This natural augmentation of inoculum has the potential to substaintially reduce application costs. *Beauveria bassiana* is a biological control agent which does not accumulate in food chains or otherwise pose any

known threat to the environment. Repeated applications at high rates under field conditions have been shown to have minimal impact on beneficial insects including honey bees and many natural enemies of various pests. Resistance to *Beauveria bassiana* has not been observed in pest populations and is expected to develop slowly or not at all. The U.S. EPA has exempted *Beauveria bassiana* strain GHA from the requirement for residue tolerances in all raw agricultural commodities. There is therefore no preharvest interval, and the restricted entry interval is only 12 hours. *Beauveria bassiana* is a good candidate for many IPM systems, because it is fully compatible (can be tank-mixed) with most chemical insecticides.

- **CRADA in Place/Name of Company**: Ithaca, New York, Mycotech Corp., Butte, Montana, (CRADA written by Mycotech Corp. and ARS-Ithaca is submitted for ARS approval; focus is on the lepidoptera complex in corn as well as lepidopteran pests of other crops).

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Colorado potato beetle; **(b) Commodity**: potatoes, eggplant, and tomatoes; **(c) Specific Endangered Pesticides**: carbofuran, oxamyl, azinphos-methyl, carbaryl.

- **(a) Key ARS Location(s)**: Ithaca, New York; **(b) Contact**: Stephen P. Wraight; **(c) CRIS Project Number**: 1907-22000-010-00D.

- **(a) Key Alternative Technology**: *Beauveria bassiana* based mycoinsecticides; **(b) Developmental Status**: Large-scale demonstration projects and research to establish spray parameters for maximizing control are in progress. EPA-registered products based on strain GHA are now available. Results from initial trials of these products in North Dakota and eastern Europe are encouraging; **(c) Estimated Time Frame to End-User**: The time frame for end-user use is difficult to estimate, as it will depend, in large part, on the capacity of the beetle to develop resistance to a number of highly effective new chemistries, including imidacloprid.

- **Constraints to Adoption**: Best efficacy is against early-instar larvae; thus careful timing and multiple, frequent applications (at 4-5 day intervals) are required to achieve acceptable control. Large numbers of spores must contact the young larvae to insure a high probability of infection. The required dose is currently more costly than many of the traditionally utilized insecticides such as carbofuran. Combined with the high costs of multiple applications, this represents the most important constraint to use in field crops. Efficacy of strain GHA is also substantially reduced under very hot, dry conditions, and this beneficial fungus cannot be tank-mixed or applied on the same day as many of the chemical fungicides commonly used for plant-disease control.

- **Positive Attributes of Alternative Technology**: There is evidence (research reported from the University of Maine) that foliar applications of *Beauveria bassiana* may increase spore titers in the soil to levels that can significantly impact populations of beetles entering the soil to pupate. These elevated titers may persist through the season (and in some cases through an annual crop rotation) and thereby contribute to the long-term suppression of beetle populations. Because the beetle larvae feed in relatively exposed positions on the potato foliage, they are susceptible to overhead spray applications. Aerial applications of strain GHA were highly effective in a recent trial in North Dakota. *Beauveria bassiana* is a biological control agent which does not accumulate in food chains or otherwise pose any known threat to the environment. Repeated applications at high rates under field conditions have been shown to have minimal impact on beneficial insects including honey bees and

many natural enemies of various pest species. Resistance to *Beauveria bassiana* has not been observed in pest populations and is expected to develop extremely slowly or not at all. U. S. EPA has exempted *Beauveria bassiana* strain GHA from the requirement for residue tolerances in all raw agricultural commodities. There is therefore no preharvest interval, and the restricted entry interval is only 12 hours. *Beauveria bassiana* is a good candidate for many IPM systems, because it is fully compatible (can be tank-mixed) with most chemical insecticides.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Container inhabiting *Aedes spp.* mosquitoes (eggs, larvae, pupae), specifically *Aedes aegypti*; **(b) Commodity**: animals and humans; **(c) Specific Endangered Pesticides**: temephos.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Don Barnard; **(c) CRIS Project Number**: 6615-32000-031-00D.

- **(a) Key Alternative Technology**: *Edhazardia aedis*, a microsporidian pathogen which is host-specific for *Aedes aegypti*; **(b) Developmental Status:** Is ready for extensive field evaluation. Possible target test sites are in Argentina, Brazil, Peru, Puerto Rico, south Florida, and south Texas; **(c) Estimated Time Frame to End-User**: 1-2 years.

- **Constraints to Adoption**: Quality control procedures are needed for mass production of the pathogen, for pathogen introduction, and for monitoring pathogen infection and persistence in the mosquito population; commercialization.

- **Positive Attributes of Alternative Technology**: Host specific, habitat specific, self-sustaining, non-polluting, safe for most invertebrates, and safe for vertebrates.

- **CRADA in Place/Name of Company:** None.

- (a) Key Issue(s): Container habitat; Aedes spp. mosquitoes (eggs, larvae, pupae).
  (b) Commodity: animals and humans; (c) Specific Endangered
  species:

- (a) APIS Location(s): Gainesville, Florida; (b) Context: Dan Brand; (c) [illegible]
  Project Number: 0615-32000-031-00D.

- (a) Key Alternative Technology: Bacillus cereus, a microsporidian pathogen which is
  host-specific for Aedes aegypti; (b) Developmental Status: Already for extensive Field
  evaluations. Possible target test sites are in Argentina, Brazil, Peru, Puerto Rico, south
  Florida, and south Texas; (c) Estimated Time to End User: 1-2 years.

- Co[illegible] Points to Adoption: Quality control procedures are needed for mass production of the
  pat[illegible]n, for inclusion introduction, and for monitoring pathogen infection and persistence
  [illegible] aquatic populations; commercialization.

Positive Attributes of Alternative Technology: Host specific, help at specific
self[illegible] non-polluting, safe for most invertebrates, and safe [illegible] vertebrates

- CRADA: [illegible] Nature of [illegible] property: None

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Pecan weevil; **(b) Commodity**: Pecans; **(c) Specific Endangered Pesticides**: Carbaryl, dimethoate, imidan, DiSyston.

- **(a) Key ARS Location(s)**: Byron, Georgia; **(b) Contact**: Bruce W. Wood; **(c) CRIS Project Number**: 6606-22000-008-00D.

- **(a) Key Alternative Technology**: New cultural and biological control methods; **(b) Developmental Status**: Research using a combination of cultural methods (i.e. early harvesting and lower limb pruning) with the use of parasitic nematodes looks promising; **(c) Estimated Time Frame to End-User**: Probably up to 4 years to end-user.

- **Constraints to Adoption**: Need more data to convincingly demonstrate effectiveness and to get the cost of nematodes down to a reasonable per acre cost.

- **Positive Attributes of Alternative Technology**: Would allow for minimal dependence on chemical pesticides and is environmentally friendly.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Mosquito larvae in estuarine and other water impoundments; **(b) Commodity**: animals and humans; **(c) Specific Endangered Pesticides**: temephos.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Don Barnard; **(c) CRIS Project Number**: 6615-32000-031-00D.

- **(a) Key Alternative Technology**: *Strelkovimermis spiculatus*, a mermithid nematode that parasitizes mosquito larvae; **(b) Developmental Status:** the agent is ready for small-scale field testing in Florida; **(c) Estimated Time Frame to End-User**: 1-3 years.

- **Constraints to Adoption**: Completion of research. Quality control procedures are needed for mass production and formulation of the parasite, for delivery in the field, and for monitoring infection and recycling rates in the mosquito population.

- **Positive Attributes of Alternative Technology**: Self-sustaining, non-polluting, safe for most invertebrates, and safe for vertebrates.

- **CRADA in Place/Name of Company:** None.

[illegible]ts Threatened by Imp[illegible]entation of FQPA ARS Program Activities

Pest(s): Mosquito larvae (Mosquitoes and other water inhabiting invertebrates, [illegible] animals and humans; (c) Specific Endangered Pesticides: [illegible].

[illegible]ation(s): Gainesville, Florida; (b) Contact: Don Barnard; (c) CRIS Number: 6615-32000-031-00D.

(a) Key Alternative Technology: *Strelkovimermis spiculatus*, a mermithid nematode that parasitizes mosquito larvae; (b) Developmental Status: the agent is ready for small-scale field testing in Florida; (c) Estimated Time Frame to End-User: 1-3 years.

Con[illegible]aints to Adoption: Completion of research. Quality control procedures are needed for [illegible]ion and formulation of the parasite, for delivery in the field, and for monitoring infection and recycling rates in the mosquito population.

Positive Attributes of Alternative Technology: Self-sustaining, non-polluting, safe for most invertebrates, and safe for vertebrates.

CRADA in Place/Name of Company: None

Selected Examples of Potential Alternatives
ARS Program Activities

C. Host Resistance and Cultural Technologies Alternatives Research

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Corn earworm and fall armyworm; **(b) Commodity**: sweet corn; **(c) Specific Endangered Pesticides**: Methomyl (Lannate), trichlorfon (Proxol or Dylox), carbaryl (Sevin).

- **(a) Key ARS Location(s)**: Tifton, Georgia; **(b) Contact**: Robert E. Lynch; **(c) CRIS Project Number**: 6602-22000-026-00D.

- **(a) Key Alternative Technology**: Novartis Bt sweet corn containing the cryIA(b) gene (Bt-11 event licensed to Monsanto); **(b) Developmental Status**: EPA has granted a label for the Southeast for planting in 1998. With grower acceptance, Bt sweet corn could reduce pesticide usage on sweet corn by an estimated 75%; **(c) Estimated Time Frame to End-User**: Technology available now.

- **Constraints to Adoption**: Concern over resistance to the Bt protein in corn earworm and fally armyworm. Protein is expressed in leaf, silk, and kernels, but needs to be ingested.

- **Positive Attributes of Alternative Technology**: Host plant resistance reduces/eliminates the need for applications of chemical pesticides.

- **CRADA in Place/Name of Company**: Novartis Seeds, Inc., CRADA No. 58-3K95-6-430, "Evaluation of Bt Transgenic Sweet Corn Hybrids for Fall Armyworm and Corn Earworm Resistance."

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Western corn rootworm, *Diabrotica virgifera*, Northern corn rootworm, *Diabrotica barberi*, Mexican corn rootworm, *Diabrotica virgifera zeae*; **(b) Commodity**: corn, grain, sorghum, soybean; **(c) Specific Endangered Pesticides**: Carbaryl, methyl parathion, carbofuran, chlorpyrifos, dyfonate, phorate, terbufos.

- **(a) Key ARS Location(s)**: Brookings, South Dakota; **(b) Contact**: Larry Chandler; **(c) CRIS Project Number**: 0500-00044-003-00D.

- **(a) Key Alternative Technology**: Transgenic corn varieties; **(b) Developmental Status**: This new technology is in the formative stages. Although the technology is being developed in private industry we are actively involved in evaluating the effectiveness of modified plants in controlling larvae of corn rootworms. The lab plays a key role in developing data to better understand the technology, to develop resistance management strategies for the technology, and to implement the technology into corn rootworm management programs, including areawide management. Field evaluation of the first group of genetically-modified corn plants is underway; **(c) Estimated Time Frame to End-User**: This technology should be available to the public sector sometime after the year 2000.

- **Constraints to Adoption**: Many growers, as well as the general public, are concerned about the release of genetically modified plants into the environment. This could limit adoption in some areas. Additionally, many foreign countries are concerned about importing genetically modified corn for food processing, etc. Growers may not be willing to risk planting these new varieties if foreign markets will not take their products. Seed costs will be higher than typical corn varieties which could also limit adoption.

- **Positive Attributes of Alternative Technology**: If successful, this technology could largely eliminate the wide spread use of soil insecticides. It will result in more of a population management tool rather than only a plant protection technique. Additionally, this technology could be used in areawide management programs and could result in wider acceptance of the areawide concept.

- **CRADA in Place/Name of Company**: CRADA in place with Monsanto Agriculture Company.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: *Heliothis virescens*, *Helicoverpa zea*; **(b) Commodity**: Transgenic cotton expressing delta endotoxin genes of Bt; **(c) Specific Endangered Pesticides**: Malathion, Sevin.

- **(a) Key ARS Location(s)**: Mississippi State, Mississippi; **(b) Contact**: Johnie N. Jenkins; **(c) CRIS Project Number**: 6406-21220-004-00D.

- **(a) Key Alternative Technology**: Bt cotton as resistant host plant; **(b) Developmental Status**: Bt cotton available since 1996; **(c) Estimated Time Frame to End-User**: More varieties in 1998 contained the Bt gene.

- **Constraints to Adoption**: Bt cotton does not control *H. zea* as well as *H. virescens*. Concerned about insect resistance. Need additional Bt genes with different mode of action or different non-Bt genes.

- **Positive Attributes of Alternative Technology**: Host plant resistance reduces/eliminates the need for applications of chemical pesticides.

- **CRADA in Place/Name of Company**: Monsanto Agricultural Company, St. Louis, Missouri--testing and evaluating transgenic coker cotton lines in Mississippi; Paymaster Technology Corp., Lubbock, Texas--testing and evaluation of certain transgenic cotton lines in Mississippi; Calgene, Inc., Davis, California--testing and evaluating transgenic cotton lines in Mississippi; Delta Pine Land Company, Scott, Mississippi--testing and evaluation of transgenic DPL cotton lines in Mississippi.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Fall armyworm; **(b) Commodity**: Corn; **(c) Specific Endangered Pesticides**: Carbaryl (Sevin), parathion, trichloron (Dylox, Proxol), Methomyl (Lannate).

- **(a) Key ARS Location(s)**: Auburn, Alabama; **(b) Contact**: Wayne Reeves; **(c) CRIS Project Number**: 6420-12000-005-00D.

- **(a) Key Alternative Technology**: Commercial corn variety with Bt gene expression throughout entire plant, including ear; **(b) Developmental Status**: Bt corn in late-planting crop rotations is being developed as a feasible alternative to the standard wheat/soybean double cropping system; **(c) Estimated Time Frame to End-User**: Technology is now commercially available.

- **Constraints to Adoption**: Probably only limited effectiveness against fall armyworm, but economics and efficacy of insecticide sprays for late planted corn is not viable anyway.

- **Positive Attributes of Alternative Technology**: Host plant resistance reduces/eliminates the need for applications of chemical pesticides.

- **CRADA in Place/Name of Company**: Pioneer Hybrid International (supplier of seed/technology is being kept informed of results).

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Silverleaf whitefly, *Bemisia argentifolii*; **(b) Commodity**: Broccoli, collards, and melons; **(c) Specific Endangered Pesticides**: Malathion.

- **(a) Key ARS Location(s)**: Charleston, South Carolina; **(b) Contact**: D. Michael Jackson; **(c) CRIS Project Number**: 6659-22000-009-00D.

- **(a) Key Alternative Technology**: Insect-resistant cultivars; **(b) Developmental Status**: Some insect-resistant germplasm has been identified, but it is of poor agronomic quality; **(c) Estimated Time Frame to End-User**: 3-4 years.

- **Constraints to Adoption**: Insect-resistant germplasm has undesirable qualities at times. Incorporation of resistance genes into acceptable cultivars will be difficult. Adequate control of whiteflies is currently achieved by imidacloprid, and there is little current use of carbamates or organophosphates. Resistance will likely develop to imidadoprid, however.

- **Positive Attributes of Alternative Technology**: Pest-resistant cultivars offer a very attractive approach to pest management. Once a resistant cultivar is produced, there is no additional cost to the grower.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Soil pests of sweetpotato (several species of *Coleoptera*); **(b) Commodity**: sweetpotatoes; **(c) Specific Endangered Pesticides**: Carbaryl, malathion, chlorpyrifos, fonofos, diazinon.

- **(a) Key ARS Location(s)**: Charleston, South Carolina; **(b) Contact**: D. Michael Jackson; **(c) CRIS Project Number**: 6659-22000-009-00D.

- **(a) Key Alternative Technology**: Development of insect-resistant cultivars; **(b) Developmental Status**: Some insect-resistant cultivars are commercially available, and additional improved germplasm is being developed; **(c) Estimated Time Frame to End-User**: Immediate to three years.

- **Constraints to Adoption**: Currently available cultivars have undesirable skin color for domestic market. Breeding for insect-resistant cultivars is laborious and time consuming. Expression of resistance may not be high enough under high pest pressures.

- **Positive Attributes of Alternative Technology**: Pest-resistant cultivars offer a very attractive approach to pest management. Once a resistant cultivar is produced, there is no additional cost to the grower.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Russian wheat aphid, greenbug, yellow sugarcane aphid, Hessian fly; **(b) Commodity**: Wheat, barley; **(c) Specific Endangered Pesticides**: Methyl parathion, malathion, dimethoate, disulfoton, chlorpyrifos.

- **(a) Key ARS Location(s)**: Stillwater, Oklahoma; **(b) Contact**: David R. Porter; **(c) CRIS Project Number**: 6217-21000-004-00D.

- **(a) Key Alternative Technology**: Host plant resistance; **(b) Developmental Status**: Greenbug-resistant wheat germplasm was released in 1992. Russian wheat aphid-resistant wheat germplasm was released in 1993. Russian wheat aphid-resistant barley germplasm was released in 1993. Yellow sugarcane aphid-resistant wheat germplasm was released in 1987. Hessian fly-resistant wheat germplasm was released in 1987; **(c) Estimated Time Frame to End-User**: Time to end user (producer) varies dependent on wheat and barley breeding industry priorities. One Russian wheat aphid-resistant wheat cultivar is now available to producers in Colorado. Russian wheat aphid-resistant barley germplasm is still being improved through the breeding process in several programs around the country. Greenbug-resistant wheat cultivars are under development in several wheat breeding programs.

- **Constraints to Adoption**: There are no material constraints to adoption. However, time needed to incorporate resistance genes from germplasm into high performance wheat and barley cultivars limits the availability of these ARS research products.

- **Positive Attributes of Alternative Technology**: Host plant resistance reduces/eliminates the need for applications of all chemical pesticides. Provides ideal foundation for an IPM approach to crop production. Provides season-long pest control with no adverse impact on the environment.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Southwestern corn borer, fall armyworm; **(b) Commodity**: Corn; **(c) Specific Endangered Pesticides**: Lorsban, Lannate, Furadan.

- **(a) Key ARS Location(s)**: Mississippi State, Mississippi; **(b) Contact**: Paul Williams; **(c) CRIS Project Number**: 6406-21000-004-00D.

- **(a) Key Alternative Technology**: Plant resistance; **(b) Developmental Status**: Corn germplasm with resistance to southwestern corn borer, fall armyworm, and other Lepidoptera has been developed and released. A gene encoding a cysteine proteinase associated with resistance has been identified in cooperation with a Mississippi State University molecular biologist. Patent application has been filed; **(c) Estimated Time Frame to End-User**: Technology is available now.

- **Constraints to Adoption**: Resistance is quantitatively inherited and difficult to transfer into elite germplasm using conventional breeding methodology. Role of cysteine proteinase in resistance has not been determined.

- **Positive Attributes of Alternative Technology**: Host plant resistance reduces/eliminates the need for applications of chemical pesticides.

- **CRADA in Place/Name of Company**: No. License agreement between DEKALB Genetics Corporation for use of the cysteine proteinase to confer insect resistance is under negotiation.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Sugarcane borer; **(b) Commodity**: Sugarcane; **(c) Specific Endangered Pesticides**: Guthion (azinphosmethyl).

- **(a) Key ARS Location(s)**: Houma, Louisiana; **(b) Contact**: William White; **(c) CRIS Project Number**: 6435-22000-007-00D.

- **(a) Key Alternative Technology**: Plant resistance and biological control; **(b) Developmental Status**: Recurrent selection for borer resistance has been established to develop resistant parental lines and progeny. Seventeen germplasm clones have been registered with ***Crop Science*** for use as parental material. At the present time, this new germplasm is being incorporated into our commercial breeding program; **(c) Estimated Time Frame to End-User**: Attempts to establish *Cotesia flavipes* in the field are presently underway. It will require an additional 2-4 years to determine if *Cotesia flavipes* is effective and economical under the temperate climate found in Louisiana.

- **Constraints to Adoption**: The use of alternative insecticides, i.e., synthetic pyrethroids, can lead to secondary pest problems, i.e., yellow sugarcane aphid. Registration is now pending for other alternative insecticide treatments, i.e., Confirm (Insect Growth Regulator). Further, resistance is not immunity and some insecticide(s) will probably be required even for resistant varieties depending upon climatic and plant growth factors.

- **Positive Attributes of Alternative Technology**: At present, the use of more resistant varieties and Integrated Pest Management (IPM) has already meant a dramatic reduction (from 4 acre applications to approximately 1 acre application per year) in the use of all insecticides for the control of the sugarcane borer. With the development of more resistant varieties, the use of biological agents, and the use of more bio-friendly insecticides, this alternative technology should have an immediate and positive impact upon the environment.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Insects infesting stored wheat such as lesser grain borer, rice weevil, sawtoothed grain beetle, rusty grain beetle, red flour beetle, and other beetle pests. Insect pests of stored corn such as maize weevil, red flour beetle, Angoumois grain moth, other beetle pests; **(b) Commodity:** stored wheat and stored corn; **(c) Specific Endangered Pesticides:** malathion and pirimiphos-methyl (Actellic) on corn.

- **(a) Key ARS Location(s):** Manhattan, Kansas; **(b) Contact:** Franklin H. Arthur; **(c) CRIS Project Number:** 5430-43000-017-00D.

- **(a) Key Alternative Technology:** Crop plants can be genetically engineered to express novel insect control genes, and characteristics that confer resistance to insects are being bred into different varieties of corn; **(b) Developmental Status:** Most of the emphasis in genetic engineering is with production systems for field crops. Work with storage pests must supplement the research with field pests; **(c) Estimated Time Frame to End-User:** This technology has already been adopted for some of the major insect pests of field crops. Similar research is being conducted with insect pests of stored corn and stored wheat.

- **Constraints to Adoption:** Most of the emphasis in genetic engineering is with production systems for field crops. Work with storage pests must supplement the research with field pests.

- **Positive Attributes of Alternative Technology:** Specific control that suppresses pests without harming beneficial insects.

- **CRADA in Place/Name of Company:** No formal CRADA; cooperative work with genetic engineering is being undertaken with Prodigne, College Station, Texas. For varietal testing, cooperative work and a CRADA is being developed with Pioneer Hi-Bred International, Inc., Johnston, Iowa.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: *Hypoderma lineatum* and *Hypoderma bovis*; **(b) Commodity**: cattle; **(c) Specific Endangered Pesticides**: endangered organophosphate - Warbex.

- **(a) Key ARS Location(s)**: Kerrville, Texas; **(b) Contact**: Sidney Kunz; **(c) CRIS Project Number**: 6205-32000-017-00D.

- **(a) Key Alternative Technology**: The cattle grub recombinant vaccine technology; **(b) Developmental Status:** already developed and licensed; **(c) Estimated Time Frame to End-User**: Product introduction could occur immediately.

- **Constraints to Adoption**: Educational program to describe control potential to producer and control specialists. Convert from a product expectation of quick knockdown and the potential to eradicate to an expectation of sustained control over a period of product use.

- **Positive Attributes of Alternative Technology**: Recombinant vaccine technology with non-replicating antigens is environmentally safe and of no health risk to the applicator or the consumer of meat products. The cost of treatment would be greatly reduced and the duration of control would be greatly extended proportional to the duration of elicited immunity.

- **CRADA in Place/Name of Company:** The technology is licensed from the USDA-ARS by Alberta/Canada Livestock Trust, Inc.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Psoroptes ovis; **(b) Commodity**: sheep and cattle; **(c) Specific Endangered Pesticides**: various endangered organophosphates and coumaphos.

- **(a) Key ARS Location(s)**: Kerrville, Texas; **(b) Contact**: Sidney Kunz; **(c) CRIS Project Number**: 6205-32000-017-00D.

- **(a) Key Alternative Technology**: Vaccine/host resistance; **(b) Developmental Status:** A candidate vaccine antigen has been defined and cloned, and a patent application has been drafted for submission. Evaluation of the recombinant protein both immunological and for efficacy will be required; **(c) Estimated Time Frame to End-User**: Estimated time to completion is 3-5 years.

- **Constraints to Adoption**: Educational program to describe control potential to producer and control specialists. Convert from a product expectation of quick knockdown and the potential to eradicate to an expectation of sustained control over a period of product use.

- **Positive Attributes of Alternative Technology**: Recombinant vaccine technology with non-replicating antigens is environmentally safe and of no health risk to the applicator or the consumer of meat products. The cost of treatment should be greatly reduced and the duration of control should be greatly extended proportional to the duration of elicited immunity.

- **CRADA in Place/Name of Company:** The technology was developed through financial assistance and collaboration with Mallinckrodt Veterinary Inc., which terminated in 1996.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Corn rootworms; **(b) Commodity**: Corn; **(c) Specific Endangered Pesticides**: Furadan.

- **(a) Key ARS Location(s)**: Akron, Colorado; **(b) Contact**: Randall L. Anderson; **(c) CRIS Project Number**: 5407-12130-004-00D.

- **(a) Key Alternative Technology**: Diverse crop rotation strategies for dryland agriculture; **(b) Developmental Status**: It has been established that there is no need for the use of insecticides to control corn rootworm if corn is rotated with other crops for more than 2 years out of corn; **(c) Estimated Time Frame to End-User**: Technology is now available.

- **Constraints to Adoption**: Need for education and technology transfer to farmers.

- **Positive Attributes of Alternative Technology**: Crop rotations that are diverse eliminate the need for many pesticides.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Rangeland grasshoppers (seven major pest species); **(b) Commodity**: mixed- or tall-grass prairie; **(c) Specific Endangered Pesticides**: malathion and carbaryl.

- **(a) Key ARS Location(s)**: Sidney, Montana; **(b) Contact**: Neal Spencer; **(c) CRIS Project Number**: 5436-22000-003-00D.

- **(a) Key Alternative Technology**: The "twice-over" rotational grazing system; **(b) Developmental Status**: The "twice-over" rotational grazing system has already been demonstrated useful for increasing ground cover by native perennial grasses and for supporting excellent beef cattle performance in the Northern Great Plains. Research documented in manuscripts indicate that twice-over grazing causes significant reductions in seven of nine major pest grasshopper species; **(c) Estimated Time Frame to End-User**: Technology is currently available.

- **Constraints to Adoption**: There are no important political or social constraints. Implementation may require some cross-fencing and/or water development. The twice-over system probably won't work in desert or inter-mountain ecosystems, and may not work in all sagebrush habitats or pallouse grasslands. However, it should work in mixed- or tall-grass ecosystems throughout the Great Plains (i.e., over about 20 percent of the western range).

- **Positive Attributes of Alternative Technology**: After start-up expenses for fencing and water development, the system runs on management inputs (time and effort) rather than petroleum-based technology (fuel and chemicals). The grazing system increases grass density and ground cover to the degree that some grasshopper species are deprived of critical bare areas for basking or for oviposition. The cooler, more mesic microhabitat delays growth and development of grasshoppers and perhaps favors some pathogens and predators. Suppressed grasshopper populations should reach outbreak levels less frequently and remain at those high levels for less time than typical infestations.

- **CRADA in Place/Name of Company**: The developer and chief proponent of the twice-over grazing system is Dr. Lee Manske, Dickenson Research and Extension Center, 470 Star Avenue, Dickenson, North Dakota.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Diamondback moth; **(b) Commodity**: Cabbage; **(c) Specific Endangered Pesticides**: Lannate and Larvin.

- **(a) Key ARS Location(s)**: Gainesville, Florida; **(b) Contact**: Everett Mitchell; **(c) CRIS Project Number**: 6615-22000-011-00D.

- **(a) Key Alternative Technology**: Cultural network using 'collard trap crop' fields. **(b) Developmental Status**: Collards are planted around the periphery of cabbage fields to 'trap' invading diamondback moths. Moths deposit their eggs on collards rather than adjacent or interior cabbage plants. Diamondback moth populations continue to recycle in collards as long as plants remain green and continue to grow. The naturally-occurring parasitoid *Diadegma insulare* also builds up numbers in the collards and helps to keep larval populations in check. This system has been tested extensively in fields ranging from 10-60 acres. In all cases, yields and quality of cabbage in the 'trap crop' fields have been as good or better than conventionally-sprayed fields. This system has resulted in a reduction of insecticide sprays for diamondback moth control by 75-100%; **(c) Estimated Time Frame to End-User**: The system is ready for full implementation by growers.

- **Constraints to Adoption**: No technical or economic constraints exist.

- **Positive Attributes of Alternative Technology**: The 'collard trap crop' system for diamondback moth control in cabbage is cost effective, resulting in a 75-100% reduction in the number of conventional insecticide sprays required for economic control. The trap crop is planted as a normal part of the cultural system for cabbage, and the area of cultivated land devoted to collards is minimal. Biological control of diamondback moth is stimulated via the build up of natural enemies in the collard crop from which they move into the cabbage field.

- **CRADA in Place/Name of Company**: No CRADAs were established, but much of the research was conducted through a Specific Cooperative Research Agreement with the University of Florida, Gainesville.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s):** Cucumber beetle, squash bug, melon aphid, corn earworm, cabbage looper; **(b) Commodity:** Vegetables (cucurbits, sweet corn); **(c) Specific Endangered Pesticides:** Carbaryl, methomyl, carbofuran, oxydemeton-methyl, dimethoate.

- **(a) Key ARS Location(s):** Lane, Oklahoma; **(b) Contact:** Sam D. Pair (in cooperation with Areawide Pest Management Research Unit, College Station, Texas); **(c) CRIS Project Number:** 6222-22000-003-00D.

- **(a) Key Alternative Technology:** Trap crops for cucurbit pests and attracticides for adult corn earworm and other noctuids; **(b) Developmental Status:** Trap crop technology already has been introduced to producers but requires fine tuning for maximum efficacy. Producers routinely apply a systemic insecticide, carbofuran, to melon fields at planting for early-season control of insect pests such as cucumber beetle, squash bug, and aphids. However, an alternative strategy consists of using trap crops of squash planted adjacent to the melons. The trap crop may be treated with a systemic insecticide to provide control thus obviating the next to apply insecticides to melons. Should carbofuran be eliminated, the producer has the option of applying kairomonal baits and synthetic pyrethroids for control of insects in the trap crop. Since the trap crop normally occupies less than 2% of the total acreage, this technique can greatly reduce pesticide usage in grower fields; attracticide technology is now being tested to determine optimum bait components, toxicant and delivery systems; **(c) Estimated Time Frame to End-User:** 2-3 years for transfer of the technologies to the end-user.

- **Constraints to Adoption:** Trap crops--Farmers generally accept the utility of using squash as a trap crop in melons but have been reluctant to consistently use the technique for a number of reasons: Carbofuran is used in very low amounts when applied with the transplant water and therefore costs are minimal; using the material over the entire field provides the producer with "insurance" that most, if not all insects, will be controlled by the systemic insecticide; effective utilization of the trap crop requires careful management, is labor intensive, and producers are generally more concerned with getting the primary crop in and preparing or planting other row crops, rather than planting or maintaining a trap crop; and squash plants mature quickly and loose their effectiveness as a trap crop. Therefore, the savings derived from decreased insecticide usage when using a trap crop is far less than the income that would be derived from planting additional melons instead of the trap crop. Attracticidal Baits--EPA considers bait components as active ingredients rather than adjuvants which will require full registration. Therefore, industry has been reluctant to

Pot[illegible]ial Alternatives of Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA

ARS Program Activities

SPE[illegible]CIFIC EXAMPLE

• (a) Key Target Pest(s): Cucumber beetle, squash bug, melon aphid, corn earworm, cabbage looper; [illegible] Commodity: vegetables (cucurbits, sweet corn); (c) Specific Endangered Pesticides: carbaryl, methomyl, carbofuran, oxydemeton-methyl, dimethoate.

• (a) Key ARS Location(s): Lane, Oklahoma; (b) Contact: Sam D. Pair (in cooperation with Areawide Pest Management [illegible]search Unit, College Station, Texas); (c) CRIS Project Number: 6223-22000-003-00D.

• (a) Key Alternative Technology: Trap crops for cucurbit pests and attracticides for adult corn earworm and other noctuids; (b) Developmental Status: Trap crop technology already has been introduced to producers but requires fine tuning for maximum efficacy. Producers routinely apply a systemic insecticide, carbofuran, to melon fields at planting for early-season control of insect pests such as cucumber beetle, squash bug, and aphids. However, an alternative strategy consists of using trap crops of squash planted adjacent to the melons. The trap crop may be treated with a systemic insecticide to provide control thus obviating the need [illegible]ly insecticides to melons. Should carbofuran be eliminated, the producer has the [illegible]ion of applying kairomonal baits and synthetic pyrethroids for control of insects in the trap crop. Since the trap crop normally occupies less than 2% of the total acreage, this [illegible] can greatly [illegible] pesticide usage in grower fields; attracticide technology is now being tested to determine optimum unit components, toxicant and delivery systems; (c) Estimated Time Frame to End-User: 2-3 years for transfer of the technologies to the [illegible]

[illegible]ments to Adoption: Trap crops--Farmers generally accept the utility of using squash as a trap crop in melons but have been reluctant to consistently use the technique for a number of reasons: Carbofuran is used at very low amounts when applied [illegible] the transplant water and therefore costs are minimal; using the material over the entire [illegible] provides the producer with "assurance" that most, if not all insects, will be [illegible] systemic [illegible]ticide; effective utilization of [illegible] trap crop requires [illegible] is labor [illegible] of [illegible] sets are gene[illegible] [illegible] planting other row crops, rather than plant[illegible] [illegible] quickly and loose the [illegible] from chemical insecticide [illegible]

invest. However, due to the possibility of using safer toxicants, industry is showing renewed interest.

- **Positive Attributes of Alternative Technology:** Both strategies are directed primarily at control of mobile early-season adult stages of the pests which theoretically should reduce overall pest population to sub-economic levels. The approach uses minimal amounts of pesticide (less than 5%) compared to the total field coverage in conventional applications, resulting in decreased pesticide inputs for growers and reduced impact on beneficial organisms.

- **CRADA in Place/Name of Company:** No CRADA is in place.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Colorado potato beetle (*Leptinotarsa decemlineata* (Say); **(b) Commodity**: Tomatoes; **(c) Specific Endangered Pesticides**: Azinphosmethyl (Guthion), phosmet (Imidan), oxampy (Vydate).

- **(a) Key ARS Location(s)**: Beltsville, Maryland; **(b) Contact**: Edward Dougherty; **(c) CRIS Project Number**: 1275-22000-142-00D.

- **(a) Key Alternative Technology**: Use of cover mulches to suppress Colorado potato beetle populations in fresh market staked tomatoes; **(b) Developmental Status**: The benefits of using cover crops as mulches have been demonstrated, and the technology is available and in use to a limited extent. Studies are underway to determine to what extent the mulches suppress insect pest populations; **(c) Estimated Time Frame to End-User**: The first phase of these studies should be completed in 1998.

- **Constraints to Adoption**: The constraints are primarily related to getting growers to adopt major changes in their farming practices. In some areas, there may also be some problems with slightly slower maturation of fruit grown in organic mulch and with not being able to fumigate under plastic.

- **Positive Attributes of Alternative Technology**: Research at Beltsville has clearly demonstrated the benefits of growing staked tomatoes using cover crops as mulches (to replace plastic) and as sources of nutrients (to reduce fertilizer inputs) in a no-tillage system that stops soil erosion and compaction, makes better use of rain water, improves yield, and increases profitability. The suppression of insect and disease pest problems would provide significant added benefits to this production system.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Plant-parasitic nematodes; **(b) Commodity**: Many agronomic and vegetable crops; **(c) Specific Endangered Pesticides**: Fenamiphos, ethoprop, aldicarb, carbofuran, Nemacur, Mocgop, Temik, Furadan, Vydate.

- **(a) Key ARS Location(s)**: Tifton, Georgia; **(b) Contact**: James Carpenter; **(c) CRIS Project Number**: 6602-22000-029-00D.

- **(a) Key Alternative Technology**: Cropping systems, resistant cultivars, tillage methods, 1-3-d soil fumigants; **(b) Developmental Status**: Some alternative technologies are developed now. Others must be developed; **(c) Estimated Time Frame to End-User**: 1-4 years.

- **Constraints to Adoption**: Economics. Resistant cultivars are not resistant to a broad-spectrum of nematodes. Farmers do not have adequate equipment for certain tillage methods. Most alternatives are less effective than organophosphate and carbamate pesticides in controlling plant-parasitic nematodes.

- **Positive Attributes of Alternative Technology**: Reduced soil and/or water pollution.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

- **(a) Key Target Pest(s)**: Tarnished plant bug (TPB); **(b) Commodity**: Cotton; **(c) Specific Endangered Pesticides**: Acephate, dicrotophos, methamidophos, profenofos alone and in mixtures with other groups of pesticides.

- **(a) Key ARS Location(s)**: Stoneville, Mississippi; **(b) Contact**: Dick Hardee; **(c) CRIS Project Number**: 6402-22000-022-00D.

- **(a) Key Alternative Technology**: Biological control; **(b) Developmental Status**: Areawide management with selective mowing and/or herbicide sprays to kill before movement to TPB from weeds to cotton. Project is in its first year of testing; **(c) Estimated Time Frame to End-User**: Project will continue for at least 3 years.

- **Constraints to Adoption**: Preliminary results are extremely encouraging but the program must be evaluated over 3 or more years. Timing of sprays and/or mowing, as well as grower compliance are critical. Spraying and mowing may reduce the number of beneficial insects. There may be a need for a grower referendum for financing and insurance of compliance. The cost does not appear to be prohibitive.

- **Positive Attributes of Alternative Technology**: No harm to the environment. It will reduce pesticide loads as well as secondary insect outbreaks.

- **CRADA in Place/Name of Company**: None.

Potential Alternatives to Organophosphate and Carbamate Pesticides Threatened by Implementation of FQPA
ARS Program Activities

SELECTED EXAMPLE

(a) Key Target Pest(s): Tarnished plant bug (TPB); (b) Commodity: Cotton; (c) Endangered Pesticides: [illegible]ephate, [illegible]crotophos, methamidophos, [illegible] used in mixtures with other groups of pesticides.

(a) K[illegible] ARS Location(s): Stoneville, Mississippi; (b) Contact: Dick Hardee; (c) CRIS Project Number: 6402-22000-022-00D.

(a) Key Alternative Technology: Biological control; (b) Developmental Status: Area wide management with selective mowing and/or herbicide sprays to kill before movement to [illegible] from [illegible] to cotton. Project is in its first year of testing; (c) [illegible]timated Time Frame to End-User: Project will continue for at least 3 years

o Constraints to Adoption: Preliminary results are extremely encouraging but the program must be evaluated over 3 or more years. Timing of sprays and/or mowing, as well as grower compliance are critical. Spraying and mowing may reduce the number of beneficial insects. There may be a need for a grower cooperative for financing and insurance of compliance. The cost does not appear to be prohibitive.

o Positive Attributes of Alternative Technology: No harm to the environment. It will reduce pesticide load, as well as secondary insect outbreaks.

[illegible] in Place/Name of Company: None.

Summary

In response to the potential loss of a number of pest control chemicals as the result of the Food Quality Protection Act of 1996, the Agency has undertaken an inventory of substitutes and alternative technologies and tactics that are in the developmental pipeline within ARS. This activity will help ARS and its partners to identify knowledge and technology gaps that need filling and to determine what is needed to fill those gaps. This initial assessment will also be of value to the Agency and others as it organizes and participates in meetings and workshops between scientists, grower and commodity groups and others to better define critical research needs beyond current programs, as well as for use when participating in informational exchange and coordination meetings.

Input for this initial inventory and status report was provided by the National Program Staff, the ARS Area Director's offices and many of the ARS field scientists. The resulting document details potential substitute and alternative technologies that are in the developmental pipeline in the areas of chemical and nonchemical research, biological control with microbes and natural enemies, cultural technologies, and host resistance. The inventory at this point has been generally restricted to potential alternative technologies for those chemical pesticides that will be first to undergo review of tolerances by EPA, as required by the Food Quality Protection Act of 1996. These include a number of organophosphates, carbamates and those pesticides that are potential B1 and B2 carcinogens. A list of the at-risk chemicals are provided with this document.

The agency requested the providers of the information to generally restrict their input to technologies that have the greatest potential of delivery to the end-user within the next 2-3 years time frame, although a few longer term alternatives are included. Each program activity includes the identification of the key target pest(s), the commodity(s), and a list of the specific at-risk pesticide(s). Both pre-harvest and post-harvest pests, as well as pests affecting man and animals are included. A description of the potential substitute technology, its developmental status, an estimated time frame to the end-user, constraints to adoption, and the positive attributes of the alternative technology also is given. Additionally, the ARS location and project involved with the development of the technology, as well as any private sector partners involved, are listed. More than 80 potential substitute and alternative technologies are described in this initial assessment. ARS intents to periodically revise this document in order to increase its completeness and to add new technologies related to the impact of FQPA as they come closer to reality.